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J952-54

An Assessment of the

United States Food and Agricultural Research System

Volume II—Commissioned Papers

Part C: Structure, Evaluation, and Funding of Food and Agricultural Research

I. Historical Analysis of Investment in Food and Agricultural Research in the United States
II. An Evaluation of Methods for Examining the Quality of Agricultural Research
III. Nature and Flow of Benefits from Ag-Food Research
IV. The Role of the Federal Government, State Agricultural Experiment Stations, and the Private Sector in Research
V. Agricultural Research in Non-Land-Grant Universities
VI. The Role of Non-Land-Grant Universities in Food and Agricultural Research
VII. Post-Harvest Technology Research
VIII. The Role of U.S. Food and Agricultural Research in International Development
IX. A Comparative Study of National Agricultural Research Systems in Selected Countries

April 1982

CONGRESS OF THE UNITED STATES
Office of Technology Assessment
Washington, D. C. 20510

Preface

This volume contains papers written for OTA to assist in preparation of the report *An Assessment of the United States Food and Agricultural Research System.* OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information than could be accommodated in the final assessment report, and are being made available for such purposes.

PART C

Commissioned Papers for

An Assessment of the United States Food and Agricultural Research System

Part C: Structure, Evaluation, and Funding of Food and Agricultural Research

I. Historical Analysis of Investment in Food and Agricultural Research in the United States--Joseph Havlicek, Jr., and Daniel Otto
II. An Evaluation of Methods for Examining the Quality of Agricultural Research--Robert E. Evenson and Brian Wright
III. Nature and Flow of Benefits from Ag-Food Research--Fred C. White, B. R. Eddleman, and J. C. Purcell
IV. The Role of the Federal Government, State Agricultural Experiment Stations, and the Private Sector in Research--A. H. Moseman, J. S. Robins, and Harold Wilcke
V. Agricultural Research in Non-Land-Grant Universities--R. C. Lewontin
VI. The Role of Non-Land-Grant Universities in Food and Agricultural Research--Charles M. Smallwood
VII. Post-Harvest Technology Research--George W. Irving, Jr., Frederic R. Senti, W. T. Pentzer, and Joseph C. Purcell
VIII. The Role of U.S. Food and Agricultural Research in International Development--William R. Furtick
IX. A Comparative Study of National Agricultural Research Systems in Selected Countries--Grahame J. C. Smith

Commissioned Paper I

HISTORICAL ANALYSIS OF INVESTMENT IN FOOD AND AGRICULTURAL RESEARCH IN THE UNITED STATES

Joseph Havlicek, Jr.
and
Daniel Otto

Office of Technology Assessment

January 1981

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Acknowledgments

Special thanks go to Betty P. Havlicek for editing the manuscript, especially the titles of the many figures and tables, and for typing all drafts of this report.

The section on priority setting and size of investment in agricultural research could not have been written without the assistance of Dr. William Flatt, Dean of the College of Agriculture at Georgia, Dr. Neal Boyd, Associate Director of Virginia Experiment Station and Associate Dean of the College of Agriculture and Life Sciences at Virginia Polytechnic Institute and State University, and Dr. Ernie Corley, Chief of Program Planning Staff of the Science and Education Administration. These individuals provided basic information about priority setting and research fund allocation and also provided constructive suggestions on that section of the report.

Dr. James B. Kendrick, Jr., Vice President for Agriculture and University Services at the University of California thoroughly read an earlier version of the report and provided penetrating and constructive suggestions which helped mold this final version of the report.

Dr. John Myers of USDA/SEA/CRIS provided the 1978 and 1979 unpublished data used in this report.

Finally, a special thanks to Dr. Mike Phillips and other personnel of OTA and members of the work group and advisory panel for their constructive suggestions and guidance.

Summary

This report deals with three rather large topics. First, patterns and trends in public expenditures on agricultural research are analyzed for total expenditures, by classifications constructed for this report, by individual commodities, by sources of funding, by performers of research, and relative to selected bases of reference. Second, the priority setting and budgeting process in the state agricultural experiment stations (SAES) and the United States Department of Agriculture (USDA) are discussed briefly and some models for allocating agricultural research resources are reviewed. Third, from a conceptual viewpoint some alternative procedures and considerations relative to future analyses and allocations of agricultural research resources are discussed.

The overall picture for public funded research indicates that expenditures by the SAES and the USDA increased in current and constant dollars during the 1966-1979 period (see Figures 1 and 2). In current dollars the increase was 204 percent for the fourteen-year period. Total current dollar research expenditures in the SAES increased 245 percent during this period, while the USDA expenditures increased 149 percent. The constant dollar expenditures which reflect the purchasing power of the agricultural research expenditures by SAES and USDA combined increased only 23 percent from 1966 to 1979. Furthermore, the constant dollar agricultural research expenditures of the USDA increased only one percent during this period, while those in the SAES increased forty percent. Scientist years devoted to agricultural research remained constant in the USDA during the 1966-1979 period and increased slightly in the SAES (see Figure 3).

Expenditures by the Agricultural Research Service (ARS) were the largest component of the total expenditures on agricultural research by the USDA and from 1966 to 1979 exhibited a 139 percent increase in current dollars but a three percent decrease in constant dollars (see Figures 4 and 5). The current dollar expenditures of the Economics and Statistical Service (ESS) increased 127 percent from 1966 to 1979 but the constant dollar expenditures decreased by eight percent. Cooperative Research (CR) obtained separate funding in 1967 and from then until 1978 increased over eleven-fold in current dollars and five-fold in constant dollars, but decreased sharply from 1978 to 1979. However, the level of expenditures of CR were small relative to the expenditures of ARS.

Funds for agricultural research at the SAES were analyzed by source of funding (see Figures 6 and 7). Of the federal research funds to the SAES, the formula funds were the largest component and in current dollars steadily increased nearly 200 percent from 1966 to 1979. In constant dollars the increase was twenty percent or about 1.5 percent per year. Funds through cooperative grants and agreements exhibit some variation and from 1966 to 1979 the current dollar expenditures increased 197 percent, while constant dollar expenditures increased twenty percent. Other federal funds to the SAES increased 129 percent from 1966 to 1979 but in constant dollars declined seven percent.

State appropriations and sales increased nearly four-fold during the 1966-1979 period, and even with the large depressing effects of inflation, the increase in constant dollar expenditures was just slightly under 57 percent (see Figures 8 and 9). State appropriations and sales were a substantially greater source of agricultural research funds to the SAES than were federal formula funds, and the increases in both current and constant dollars in state appropriations and sales overshadowed the increases in federal formula funds. Funds from private sources were a small but increasingly important part of the total agricultural research funds at the SAES. During the 1966-1979 period funds from private sources increased four-fold in current dollars and 63 percent in constant dollars.

Expenditures by private industry on agricultural research per se are not available. However, some data were available for the 1963-1975 period for applied research and development for agricultural related products. Except for a slight dip in 1972, expenditures by private industry on applied research and development for agriculture related products increased 170 percent in current dollars from 1963 to 1975 and increased 39 percent in constant dollars. Relative to the expenditures by the SAES and USDA on agricultural research, the expenditures by private industry on applied research and development on agricultural related products in 1975 was 23 percent greater than the SAES and 75 percent greater than the USDA expenditures on agricultural research. Of course, what is not known in these comparisons is just how much of the expenditures by private industry may have been devoted to the development of private brands and marketing strategies.

Expenditures for agricultural research were separated into expenditures on production research, post-harvest technology (PHT) research, and other food and agricultural research. PHT includes agricultural marketing and was defined in terms of selected RPA's. Patterns in these three components of total agricultural research were examined for the 1966-1979 period for the SAES, USDA, and SAES and USDA combined (see Figures 11 and 12). Production research for the USDA and SAES combined was the largest component of total agricultural research and exhibits patterns similar to those for total agricultural research. Current dollar expenditures on production increased 218 percent from 1966 to 1979 while constant dollar expenditures increased 28 percent.

Expenditures on PHT research accounted for about 24 percent of total agricultural research funds of the USDA and SAES combined in 1966 and approximately 19 percent in 1979. In current dollars the expenditures on PHT research by the USDA and SAES combined increased 143 percent from 1966 to 1979, but the constant dollar expenditures decreased 1.5 percent.

Production research was the largest component of total research expenditures in the USDA and during the 1966-1979 period current dollar expenditures on production research increased 170 percent, while constant dollar expenditures varied considerably and increased only nine percent (see Figures 13 and 14). Expenditures on PHT research in the USDA ranged from 35 percent of total research expenditures in 1966 to 29 percent in 1979. The current dollar expenditures on PHT research increased by 107 percent from 1966 to 1979 but decreased sixteen percent in constant dollars. Current dollar expenditures on other agricultural research increased by 191 percent from 1966 to 1979 but constant dollar expenditures decreased by sixteen percent.

Patterns of agricultural research expenditures in the SAES are not very different from those in the USDA (see Figures 15 and 16). Expenditures on production research were the largest components of total agricultural research expenditures and from 1966 to 1979 increased 241 percent in current dollars and 23 percent in constant dollars. Expenditures on other agricultural research were approximately the same magnitude as those for PHT research but increased a little more rapidly in both current and constant dollars than did the expenditures on PHT research. Each accounted for about one-seventh of the total agricultural research expenditures during the 1966-1979 period.

Analysis of patterns in agricultural research expenditures by private industry had to rely on data pertaining to applied research and development expenditures on food and kindred products, agricultural chemicals, and farm machinery. Food and kindred products research is most comparable to the PHT research in the USDA and SAES. Expenditures on applied research and development for food and kindred products were the largest of the three components and were the only expenditures which increased steadily during the 1963-1975 period (see Figures 17 and 18). During this period research on food and kindred products accounted for nearly one-half of the total expenditures on applied research and development for agricultural related products. Current dollar expenditures by private industry for applied research and development on food and kindred products increased 186 percent from 1963 to 1975 while constant dollar expenditures increased 47 percent. Expenditures by private industry on applied research and development for agricultural chemicals and farm machinery varied erratically during the 1963-1975 period.

The patterns in expenditures by the SAES and the USDA on PHT and total agricultural research were further analyzed for the 1966-1979 period for twelve selected agricultural commodities. The twelve selected commodies were potatoes, other vegetables, sorghum, corn, wheat, soybeans, rice, small grains, cotton, cotton seed, dairy, and beef. Patterns in both current and constant dollars for PHT and total agricultural research for each commodity by the SAES and USDA were analyzed (see Figures 19-42). The expenditures of the SAES and USDA on total and PHT research for the twelve commodities exhibited several unique patterns in terms of levels and variation of funding, but some general tendencies did exist which allow the following general conclusions to be drawn:

1. In general the total expenditures on research of specific commodities were greater in the SAES than in the USDA. Cotton and cotton seed were two exceptions for which expenditures in the USDA were greater than those in the SAES.

2. Current dollar research expenditures by both the SAES and the USDA for a commodity increased from 1966 to 1979, but the constant dollar expenditures increased very slightly or not at all and some commodities declined rather substantially.

3. The loss of purchasing power during the 1966-1979 period because of inflation was very substantial, and the real dollars available for agricultural research in both the SAES and the USDA remained at about the same level over the fourteen-year period.

4. In general the level of expenditures and the promotion of expenditures allocated to post-harvest technology and agricultural marketing research were greater in the USDA than in the SAES.

5. In both the SAES and the USDA current dollar expenditures for PHT research increased over the 1966-1979 period, however, from 1977 to 1979 the levels of expenditures for several commodities decreased.

6. In both the SAES and the USDA constant dollar expenditures for PHT research exhibited only slight increases or declined over the 1966-1979 period.

In order to view the expenditures on PHT and total agricultural research from a different perspective, the research expenditures were measured on a per scientist year and per $1000 value of agricultural output basis. Total agricultural research expenditures per scientist year steadily increased during the 1966-1979 period for the SAES, USDA, and SAES and USDA combined. The expenditures per scientist year were higher in the USDA than in the SAES and in current dollars ranged from $42,822 in 1968 to $110,460 per scientist year in 1979 (see Figure 43 and 44). In constant dollars the corresponding range was from $41,419 per scientist year in 1970 to $46,944 in 1979. For the SAES the range in current dollar expenditures per scientist year went from $33,390 in 1966 to $98,484 in 1978, while in constant dollars the corresponding range per scientist year was from $32,610 in 1967 to a high of $46,010 in 1977. From 1966 to 1979 the constant dollar expenditures per scientist year for total agricultural research increased ten percent at the SAES and only seven percent at the USDA.

The per scientist year expenditures on PHT research at the SAES and USDA exhibit similar patterns for the 1966-1979 period. From 1966 to 1979 expenditures on PHT research per scientist year increased 148 percent in current dollars and remained at about the same level in constant dollars although they varied considerably throughout the period (see Figures 45 and 46). In current dollars the per scientist year expenditures on PHT research were $30,892 at the SAES and $35,557 at the USDA in 1966 and $89,126 at the SAES and $85,940 at the USDA in 1979. The constant dollar expenditures on PHT research per scientist year were $32,415 in 1966 to $37,877 in 1979 at the SAES and from $37,310 in 1966 to $36,523 in 1979 at the USDA.

In comparison the private industry costs per scientist year on food and kindred products, chemicals, and all private industry show that for the 1963-1975 period the current dollar costs per scientist year increased (see Figure 54 and 55). But more striking is the pattern in constant dollars, which shows that the R & D costs per scientist year decreased during the 1963-1975 period.

Expenditures on total agricultural research per $1000 value of agricultural production varied during the 1966-1979 period and exhibit a less distinct trend, reflecting the fact that the value of agricultural output possesses a trend of its own. The focal point for any patterns in total agricultural research expenditures per $1000 value of agricultural output is the sharp decrease from 1972 to 1973 which in part is due to the favorable agricultural prices in 1973 (see Figure 47). Thereafter the expenditures steadily increased to a high of $5.66 per $1000 value of of production in 1977 and then declined to $4.79 per $1000 of production in 1979. In the USDA the expenditures per $1000 value of agricultural production varied from 1966 to 1979 but declined overall from $3.06 per $1000 value of production in 1966 to $2.57 per $1000 value of production in 1979.

Expenditures on PHT research in the SAES per $1000 value of agricultural production increased from 66 cents in 1966 to a high of 85 cents in 1977 and then declined to 67 cents in 1979 (see Figure 48). In the USDA the PHT expenditures per $1000 value of agricultural production increased from $1.08 in 1966 to a high of $1.15 in 1971 and then declined to a low of 76 cents in 1979.

Some additional comparisons of PHT and total agricultural research expenditures relative to other reference points indicate that the SAES share of total public expenditures on agricultural research ranged from a low of 56 percent in 1967 to 65 percent in 1979 (see Figure 49). The SAES share of expenditures on PHT research ranged from a low of 37 percent in 1967 to a high of 47 percent in 1979.

Current and constant dollar expenditures for all research and development during the 1966-1978 period by selected federal agencies such as NASA, DOE, NSF, USDA, DOD, HEW and other selected agencies are presented in Figures 50-53. Current and constant dollar expenditures on PHT, production, other agricultural research by the USDA for the 1966-1979 period were analyzed separately for ARS, ESS, and CR (see Figures 56-61). Total current dollar expenditures on agricultural research increased from 1966 to 1979 in all three services but constant dollar expenditures for the same period increased only in CR. The expenditures of CR refer to funds used within USDA for administering research funds in states and to obligations of CR administered special grants.

In terms of expenditures on agricultural research, ARS is the largest of the three services considered and production research constituted the largest part of its total research expenditures. In current dollars the expenditures on production research increased by 166 percent from 1966 to 1979 while constant dollar expenditures increased only six percent (see Figures 56 and 57). Current dollar expenditures in ARS on PHT research increased steadily from 1966 to 1979 but constant dollar expenditures declined by 24 percent. Expenditures on other research are a small component of ARS research expenditures and increased in current dollars but remained at about the same level in constant dollars.

The largest component of ESS agricultural research expenditures is expenditures on PHT research which includes agricultural marketing research. In current dollars the expenditures on PHT research increased by 177 percent from 1966 to 1979 and constant dollar expenditures increased twelve percent (see Figures 58 and 59). The current dollar expenditures on production research in ESS increased only three percent from 1966 to 1979 while constant dollar expenditures declined 58 percent. Expenditures in ESS on other research exhibited an erratic pattern from 1966 to 1979 and overall current dollar expenditures increased 116 percent and constant dollar expenditures declined thirteen percent.

In CR both current and constant dollar expenditures on production research increased substantially for the time period considered. Current dollar expenditures on PHT research fluctuated substantially and constant dollar expenditures increased by 43 percent from 1972 to 1979 (see Figures 60 and 61). Expenditures on other research are small in CR and declined from 1972 to 1979 in both current and constant dollars.

SAES obtain funds for production, PHT, and other agricultural research from federal and non-federal sources. Federal formula funds including regional research funds, cooperative grants and agreements, and other federal research funds constitute the federal sources of research funds to the SAES. The non-federal funds to the SAES consist of state appropriations and sales and research funds from private sources. Expenditures on production, PHT, and other agricultural research from all of these sources increased in current dollars during the 1966-1979 period (see Figures 63-68). Constant dollar expenditures on production, PHT, other, and total research increased from 1966 to 1979 except expenditures on PHT research from cooperative grants and agreements which declined by 22 percent and constant dollar expenditures on production and all agriculture research funded from other federal sources which declined by seven and twelve percent, respectively.

State appropriations and sales are the largest sources of agricultural research funds for the SAES. Current dollar expenditures from state appropriations and sales increased 288 percent from 1966 to 1979 and constant dollar expenditures increased 57 percent. Expenditures on production research were the largest component and in current dollars increased 261 percent during the period, while constant dollar expenditures increased fifty percent. Current and constant dollar expenditures on PHT research funded from state appropriations and sales increased 299 and 62 percent, respectively. Patterns of expenditures on other research are similar to the patterns for PHT expenditures but exhibit slightly greater increases.

Funds from private industry sources were a small part of the total agricultural research funds at the SAES. But from 1966 to 1969 both current and constant dollar expenditures increased substantially for production, PHT, and other agricultural research.

Special attention was focused on expenditures for production, PHT, and other agricultural research supported by regional research funds. With few minor exceptions the expenditure patterns in the Northeastern, Southern, North Central and Western Regions exhibited in Figures 71-78 were similar to the SAES total regional research expenditures. The following observations were characteristics of all four regions.

1. Current dollar expenditures on regionally funded agricultural research increased during the 1966-1979 period, but expenditures on all types of research decreased from 1978 to 1979.

2. Constant dollar expenditures on research funded under regional research declined from 1966 to 1979.

3. Production research was the dominant component of expenditures on research funded under regional research. Current dollar expenditures on production research funded under regional research increased from 1966 to 1979. Constant dollar expenditures increased slightly from 1966 to 1979 in the North Central and Western Regions but declined slightly in the Northeastern and Southern Regions.

4. Other research was the smallest component of expenditures on research funded under regional research. The current dollar expenditures on other research increased in all four regions from 1966 to 1979. Constant dollar expenditures increased in the Northeastern, Southern, and Western Regions from 1966 to 1979 but declined in the North Central Region.

5. Current dollar expenditures on PHT research funded under regional research increased from 1966 to 1978 but decreased from 1978 to 1979. Constant dollar expenditures on PHT research funded under regional research declined from 1966 to 1979 with much of the decline occurring during the latter three years of the fourteen-year period.

Priority setting and the budgeting process in the SAES and USDA are complex decentralized activities. In both the SAES and the USDA the priority setting and budgeting process is a continuous process utilizing information and guidance from research scientists, administrators, legislators, advisory boards, producer groups, consumer groups, processors, and other interested clientele. In both the SAES and the USDA interested parties can contribute their information or guidance at any stage or level within the priority setting and budgeting process.

In the SAES, priority setting and budgeting occurs at the individual station level and at the combined agricultural experiment station levels. The latter level is crucial because it is concerned with federal agricultural research funds to the states. Much of the priority setting and budgeting at that level is handled by the Legislative Subcommittee of Experiment Stations Committee on Policy. Priority setting and budgeting at individual stations varies considerably among experiment stations; but, regardless of the differences in formal structure, the research scientist is a key element in determining priorities and in determining the magnitude of funds to be allocated to alternative research areas.

The priority setting and budgeting process in the USDA is not dramatically different from that in the SAES. The research scientist is also a key element in the priority setting and budgeting process. Priority setting and budgeting occur at three major levels in the USDA. First, there are task force teams organized around decision units (DU) which develop priorities from researchers and liaison staff personnel from action and regulatory agencies. The second level entails the heads and key managers of interested agencies where research areas of common interest are identified and priorities and budgets are developed for these. The third level is that of the Secretary of Agriculture where all priorities and budgets emerging from the lower levels of administration are merged with those of the Secretary's Office, taking into consideration the guides from OMB and Congress.

Neither the SAES nor the USDA have a formal structure for handling urgent and emergency types of problems. These kinds of problems may be called to the attention of researchers or administrators in the SAES or USDA through any number of sources within the institutions or outside the institutions. Sometimes the researchers identify the problem and initiate action, while at other times the problem is identified by extension personnel, other federal personnel such as those of the Animal Protection and Health Inspection Service (APHIS), producers, or agricultural industry personnel. Actions are initiated to fill in gaps on information and to generate additional information needed to solve the problem causing the emergency situation. Both the SAES and USDA have a respectable track record at expediently altering priorities, reallocating resources, and providing solutions to emergency problems.

A few selected allocation models for allocating resources in agricultural research are summarized in the report. There is little evidence that these models are being used extensively. The major problem appears to be the number of scientists and administrators and the time required from them to make these allocation models operational. Although the models utilize rigorous and objective tools, the data and information required of scientists and administrators is quite subjective. These models do have some value in providing a more formal conceptual framework to a process that involves many informal components.

The final section of this report deals with some conceptual issues related to financing agricultural research. The three issues considered are research duplication, alternative measures of impact of agricultural research, and supplemental approaches to financing agricultural research. In the discussion of duplication of research both research which actually duplicates previous or current research and apparently duplicative research which appears to duplicate other research are considered. Duplicative research may merit being done to verify or refute previous discoveries or research findings. The duplicative research also may beneficially complement educational and extension programs. Research which appears to duplicate other research but which is being performed under different conditions may be necessary for adaptations, verification, and generalization of research findings. Furthermore, the existence of similar work, which appears duplicative, in different locations may lead to positive interactions which may subsequently increase the value of both research efforts. Also, there may be beneficial interactions with extension and educational programs.

Alternatives to measuring the impacts of agricultural research in terms of changes in agricultural output, changes in value of agricultural output, and changes in agricultural productivity are discussed. All three of these measures focus on the producer level whereas impacts of PHT research and other types of agricultural research such as rural development, environmental quality, resource conservation, etc., are not expected to occur at the producer level. Using value added for PHT research and levels of nutritional and quality improvement for development research are cited as alternatives which might improve further research evaluation and which merit research consideration.

The last conceptual issue discussed is concerned with achieving a more optimal allocation of research funds. Focus is on identifying marginal benefits and rates of returns to investment in various types of research and among regions. Identifying these rates of return to regions and commodities could be pursued as an empirical issue with major implications for allocation of research funds. The final alternative approach considered is an allocation scheme for private and public financing of agricultural research. The public good nature of agricultural research may not apply in all cases and a system for public and private sharing of research costs merits consideration. Such a system would require the levels and distribution of costs and benefits of a research effort to be determined before the research was ever conducted and beneficiaries could help finance all or part of the research according to the benefits received. This type of approach merits consideration in cases where in the short run, the benefits from the research accrue to a few clearly definable private individuals or firms.

Introduction

This report focuses on an historical analysis of investment in food and agricultural research in the United States and selected regions of the United States. Particular emphasis is given to research in post-harvest technology and marketing of agricultural and food products. In this report post-harvest technology (PHT) research will also include agricultural marketing research. Post-harvest technology encompasses all the functions from harvest to consumption. Thus it includes storage at various levels of the marketing channel, assembly, processing, packaging, warehousing, transportation, and distribution of agricultural and food products through the institutional food trade and wholesale and retail outlets.[1] Post-harvest technology encompasses everything from production to getting the food products to the final consumer. Research concerned with nutrition and all research dealing with forestry and wood products are excluded from post-harvest technology and agricultural marketing research.

The particular research problem areas (RPA's) included in post-harvest technology and agricultural marketing are presented in Table 1. Most of the RPA's dealing with post-harvest technology and agricultural marketing are contained in research goals IV, V, VI and VII.[2] None of the RPA's in goals I, II, and VIII were judged to contain any post-harvest technology and agricultural marketing research. All of the research in some RPA's is concerned with post-harvest technology and agricultural marketing while for some RPA's only part of the research is really post-harvest technology and agricultural marketing. For these latter RPA's information is not available to allocate the proportions of the total expenditure for the RPA to post-harvest technology and agricultural marketing and to the other type of research. Thus, if any part or all of the research in a particular RPA was concerned with post-harvest technology or agricultural marketing problems, the entire expenditure for that RPA was considered in post-harvest technology and agricultural marketing. This criterion will lead to an overstatement of the amount of funds allocated to post-harvest technology and agricultural marketing in some RPA's. This criterion was selected over the alternative which was to exclude RPA's which were not totally concerned with post-harvest technology and agricultural marketing. Excluding these RPA's would result in an understatement of the funds allocated to post-harvest technology and agricultural marketing.

Trends in Total Investment in Food and Agricultural Research

Performers of agricultural research are the United States Department of Agriculture (USDA), State Agricultural Experiment Stations (SAES), including the 1890 schools and Tuskegee, and private industry. The research of the USDA and SAES constitutes public research regardless of the source of funds for the research. USDA agricultural research is funded from federal sources while federal funds, state appropriations and sales, and private sources support research of the SAES.

Agricultural research performed by private industry is difficult to deal with because of the lack of reliable data. It is not even possible to identify all of the performers of agricultural research in private industry. Those in private industry engaged in agricultural research are not required to identify themselves nor are they required to publicly disclose their investments in agricultural research. Thus, any analysis of agricultural research by private industry has to be based on incomplete data.

In this section attention is first devoted to the pattern of total expenditures on agricultural research in the USDA and SAES for the period 1966-1979. Both current dollar and constant dollar expenditures were adjusted for inflation and were obtained by dividing the current dollar expenditures by the implicit deflator for government purchases of goods and services. This deflator, along with some other commonly used deflators, is presented in Table A-1, Appendix A. The implicit deflator for government purchases of goods and services was chosen as the most appropriate deflator because it had been designed to account for inflation in the types of goods and services for which agricultural research funds had been used.

The analysis of the pattern of total expenditures on agricultural research in the USDA and SAES is followed by an analysis of the trends in expenditures for agricultural research in the aggregate by source of funding. Finally, patterns in the limited data for agricultural research in private industry are analyzed.

TABLE 1

RESEARCH PROBLEM AREAS (RPA's) INVOLVED IN POST-HARVEST TECHNOLOGY (PHT) AND AGRICULTURAL MARKETING

GOAL I: INSURE A STABLE AND PRODUCTIVE AGRICULTURE FOR THE FUTURE THROUGH WISE MANAGEMENT OF NATURAL RESOURCES

No RPA's

GOAL II: PROTECT FORESTS, CROPS AND LIVESTOCK FROM INSECTS, DISEASE AND OTHER HAZARDS

No RPA's

GOAL III: PRODUCE AN ADEQUATE SUPPLY OF FARM AND FOREST PRODUCTS AT DECREASING REAL PRODUCTION COSTS

316 Farm Business Management

GOAL IV: EXPAND THE DEMAND FOR FARM AND FOREST PRODUCTS BY DEVELOPING NEW AND IMPROVED PRODUCTS AND PROCESSES AND ENHANCING PRODUCT QUALITY

403 New and Improved Fruit and Vegetable Products and By-products
404 Quality Maintenance in Storing and Marketing Fruits and Vegetables
406 New and Improved Food Products from Field Crops
407 New and Improved Feed, Textile, and Industrial Products from Field Crops
408 Quality Maintenance in Storing and Marketing Field Crops
410 New and Improved Meat, Milk, Eggs, and Other Animal Food Products
411 New and Improved Non-Food Animal Products
412 Quality Maintenance in Marketing Animal Products

GOAL V: IMPROVE EFFICIENCY IN THE MARKETING SYSTEM

501 Improvement of Grades and Standards--Crop and Animal Products
*503 Efficiency in Marketing Agricultural Products and Production Inputs
506 Supply, Demand and Price Analysis--Crop and Animal Products
507 Competitive Interrelationships in Agriculture
508 Development of Domestic Markets for Farm Products
509 Performance of Marketing Systems
510 Group Action and Market Power
511 Improvement in Agricultural Statistics

GOAL VI: EXPAND EXPORT MARKETS AND ASSIST DEVELOPING NATIONS

601 Foreign Market Development
604 Product Development and Marketing for Foreign Markets

GOAL VII: PROTECT CONSUMER HEALTH AND IMPROVE NUTRITION AND WELL-BEING OF THE AMERICAN PEOPLE

701 Insure Food Products Free of Toxic Residues from Agricultural Sources
702 Protect Food and Feed Supplies from Harmful Micro-organisms and Naturally Occurring Toxins
703 Food Choices, Habits, and Consumption
704 Home and Commercial Food Service
707 Prevent Transmission of Animal Diseases and Parasites to Man
708 Human Nutrition

GOAL VIII: ASSIST RURAL AMERICANS TO IMPROVE THEIR LEVEL OF LIVING

No RPA's

GOAL IX: PROMOTE COMMUNITY IMPROVEMENT INCLUDING DEVELOPMENT OF BEAUTY, RECREATION, ENVIRONMENT, ECONOMIC OPPORTUNITY, AND PUBLIC SERVICES

901 Alleviation of Soil, Water, and Air Pollution and Disposal of Wastes

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*This RPA incorporates research formerly included under RPA's 503, 504, and 505.

Total USDA and SAES

Current dollar expenditures on total agricultural research for the USDA, SAES, and the USDA and SAES combined for the 1966-1979 period are presented in Figure 1 and the constant dollar expenditures are shown in Figure 2. The top line in each figure represents the expenditures of the USDA and SAES combined, i.e., the funding of public agricultural research in the U.S. In current dollars the total funding for public agricultural research increased 204 percent for the fourteen-year period. Total research expenditures in the SAES increased 245 percent during this period, while the USDA expenditures increased only 149 percent.

But the funding picture shown in Figure 2 is quite different. For this figure the expenditures were adjusted to 1967 constant dollars (deflated). The increase in the purchasing power of the total SAES and USDA agricultural research expenditures increased only 23 percent from 1966 to 1979. Furthermore, the constant dollar agricultural research expenditures of the USDA increased only one percent during this period, while those in the SAES increased 40 percent. Clearly during this fourteen-year period and particularly during the latter part of the period, inflation has severely eroded the purchasing power of agricultural research funds. Moreover, the constant dollar expenditures of the USDA remained at about the same level during this period, so that the modest increase that occurred is attributable to the expenditures of the SAES. During the 1966-1979 period SAES expenditures have accounted for an increasingly greater share of public agricultural research funds.

During the same fourteen-year period USDA scientist years devoted to agricultural research remained nearly constant after a slight decrease from 1967 to 1968. This is evident from Figure 3. In the SAES there was a very gradual upward trend in the scientist years in agricultural research, and the total increase from 1966 to 1979 was approximately 460 scientist years. The increases in expenditures on agricultural research by the USDA and SAES have basically been used to cover the salaries and supporting research equipment and supplies for a nearly constant scientist manpower force. Yet during this same fourteen-year period the demands on agricultural research have been as great as ever.

USDA by Components

The agricultural research expenditures in current dollars of the major agencies within USDA are presented in Figure 4 and the corresponding constant dollar expenditures are presented in Figure 5. For the period 1966 to 1979 the Agricultural Research Service (ARS) was by far the largest component in terms of expenditures on agricultural research. In current dollars ARS expenditures on agricultural research have increased 139 percent from 1966 to 1979, but in constant dollars have decreased about three percent.

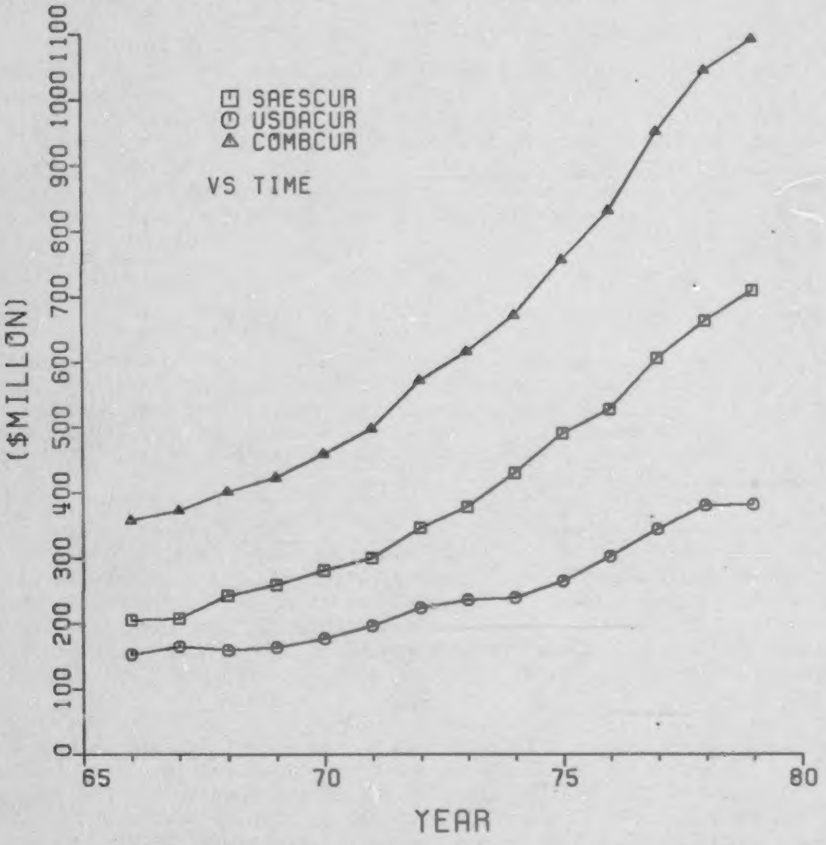
Cooperative Research (CR) obtained separate funding in 1967 and in current dollars these funds increased over eleven-fold from 1967 to 1978 but decreased nearly 30 percent from 1978 to 1979. Even in constant dollars the increase from 1967 to 1978 was over five-fold; but because the level is so small relative to ARS, the increase is difficult to perceive in Figures 4 and 5. These expenditures of CR include only the funds used within USDA for administering research funds in the states and obligations of CR administered special grants. These CR expenditures are not double-counted in any of the SAES expenditures from federal sources and are consistent with CRIS accounting procedures.

Except for slight decreases from 1967 to 1968 and 1969 to 1970, the current dollar expenditures on agricultural research by the Economics and Statistical Service (ESS, formerly ESCS) increased rather steadily during the fourteen-year period and there was a 127 percent increase from 1966 to 1979. However, this increase did not keep up with inflation during the period, and in constant dollars there was an eight percent decrease from 1966 to 1979.

SAES by Source of Funds

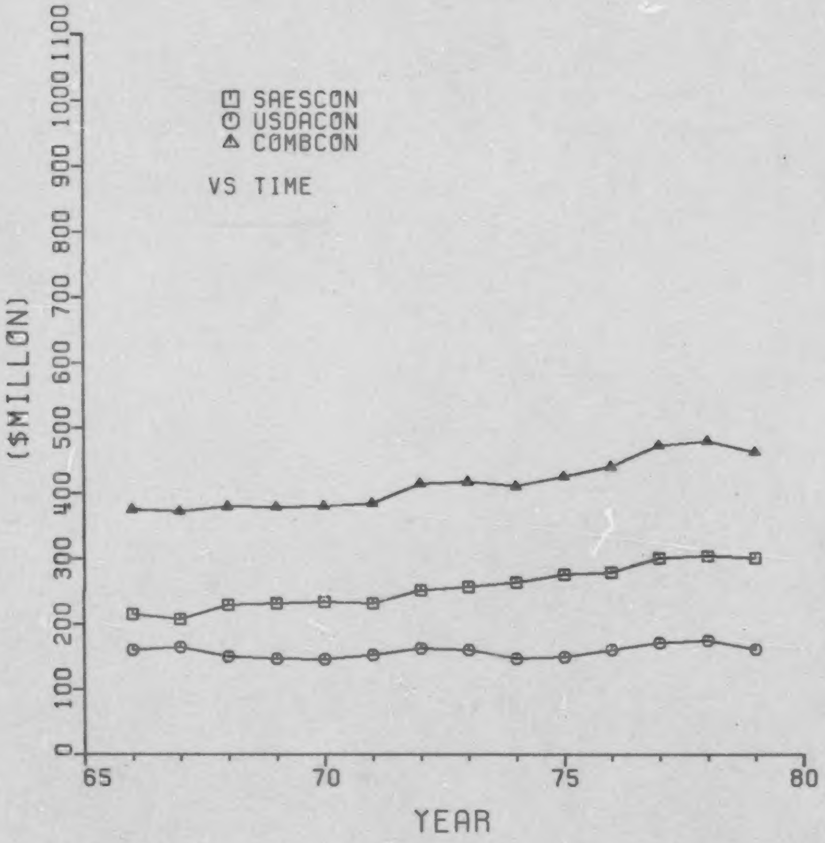
The levels of expenditures on agricultural research by the SAES for the period 1966-1979, according to major components of federal research funds, are presented in current dollars in Figure 6 and in constant dollars in Figure 7. The largest component from federal sources was the total of the formula funds, including Hatch and other appropriations. In current dollars these expenditures steadily increased from 1966 to 1979, with the 1979 level nearly 200 percent greater than the 1966 level. However, in constant dollars the current dollar increase translates to a 20 percent increase, or an average increase of about 1.5 percent per year.

FIGURE 1. SAES, USDA, AND COMBINED SAES AND USDA TOTAL RESEARCH EXPENDITURES IN CURRENT DOLLARS, 1966-1979.



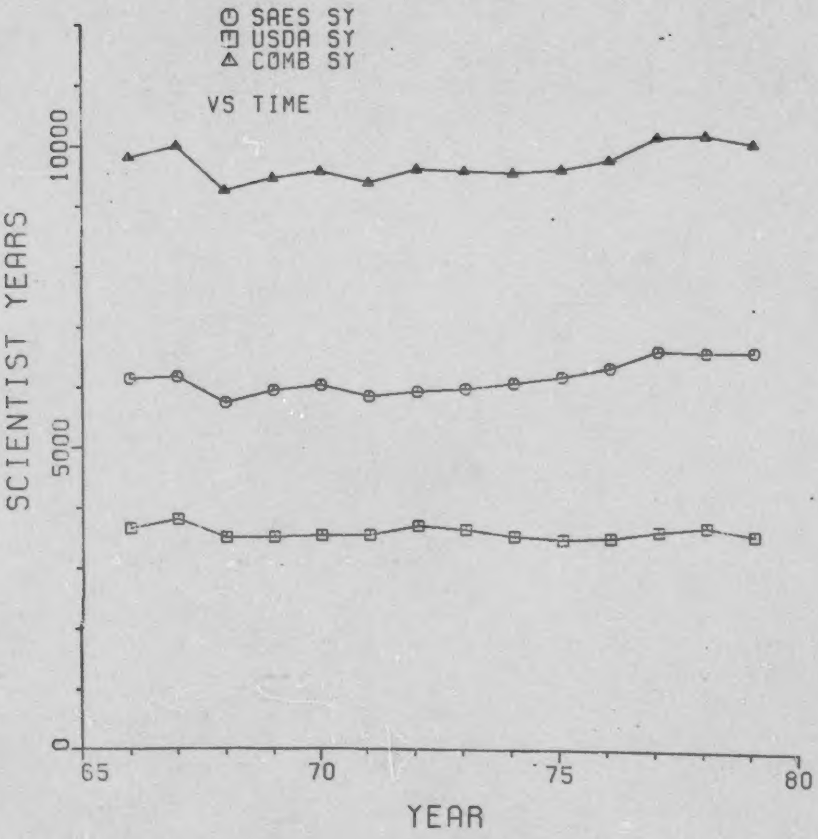
SOURCE: TABLE A-2.

FIGURE 2. SAES, USDA, AND COMBINED SAES AND USDA TOTAL RESEARCH EXPENDITURES IN CONSTANT DOLLARS, 1966-1979.



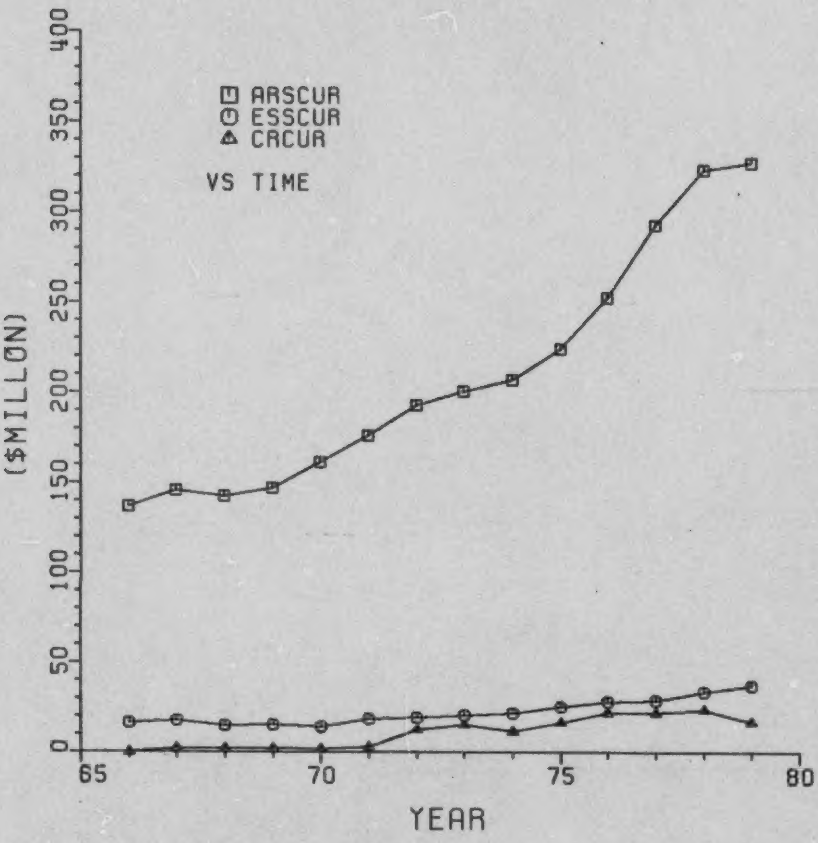
SOURCE: TABLE A-2.

FIGURE 3. SAES, USDA, AND COMBINED USDA AND SAES SCIENTIST YEARS, 1966-1979.



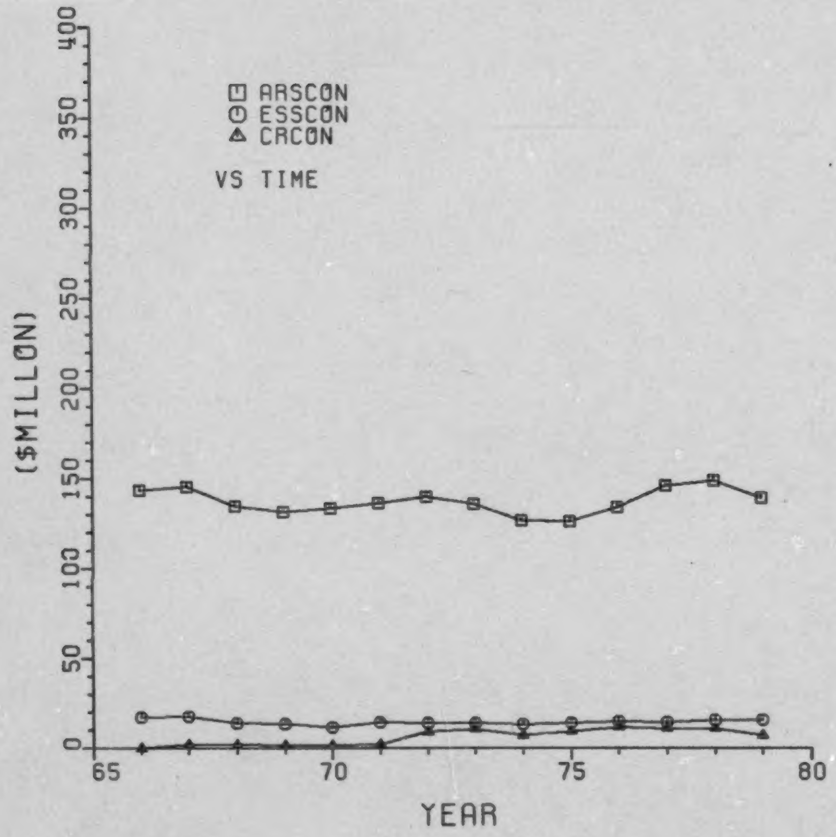
SOURCE: TABLE A-3.

FIGURE 4. USDA RESEARCH EXPENDITURES BY ARS, ESS, AND CR IN CURRENT DOLLARS, 1966-1979.



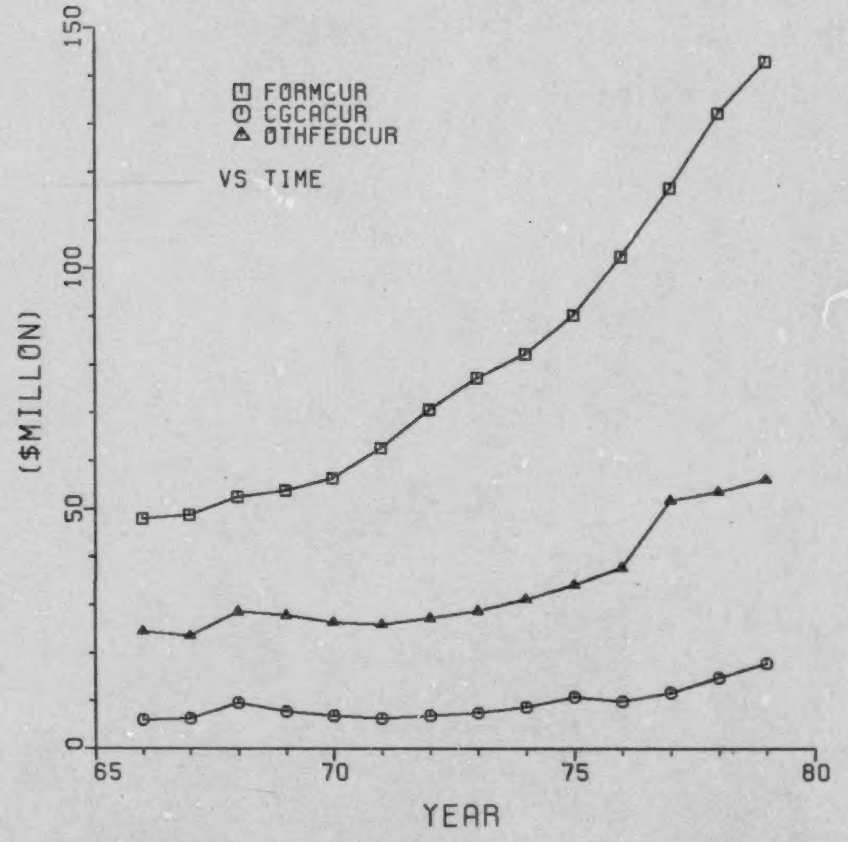
SOURCE: TABLE A-4.

FIGURE 5. USDA RESEARCH EXPENDITURES BY ARS, ESS AND CR IN CONSTANT DOLLARS, 1966-1979.



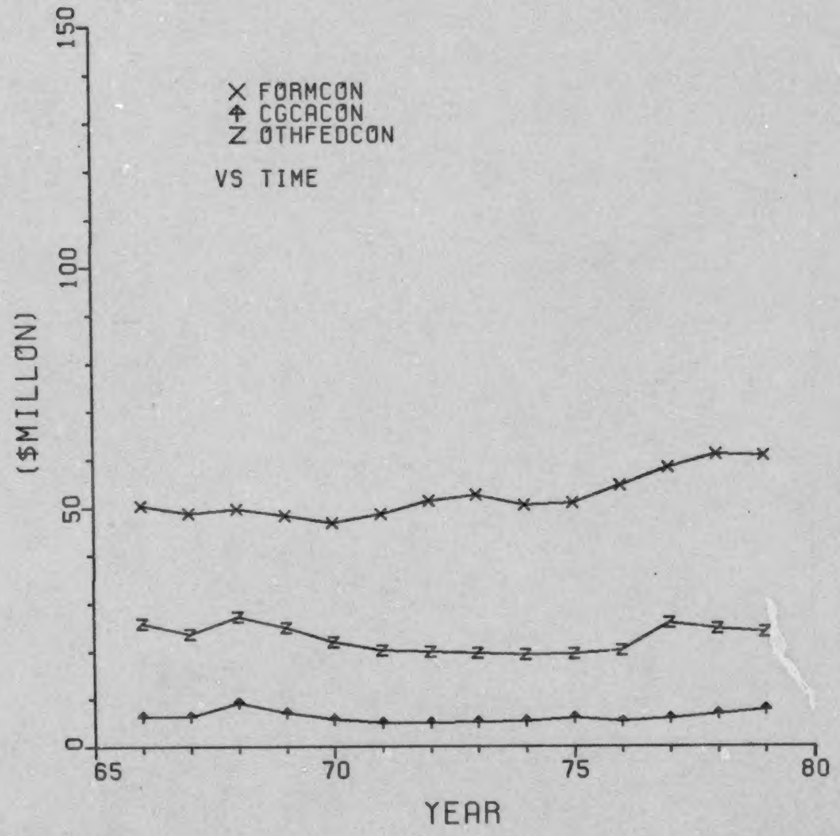
SOURCE: TABLE A-4.

FIGURE 6. FORMULA, CGCA, AND OTHER FEDERAL FUNDED RESEARCH EXPENDITURES AT SAES IN CURRENT DOLLARS, 1966-1979.



SOURCE: TABLE A-5.

FIGURE 7. FORMULA, CGCA, AND OTHER FEDERAL FUNDED RESEARCH EXPENDITURES AT SAES IN CONSTANT DOLLARS, 1966-1979.



SOURCE: TABLE A-5.

Cooperative grants and cooperative agreements (CGCA) was the smallest component of federal funding of agricultural research in the SAES. In both current and constant dollars these funds declined from 1968 to 1971, but since then have been increasing. Over the entire fourteen-year period the current dollar expenditures increased 197 percent, while the constant dollar expenditures increased only 20 percent.

Other federal funds for agricultural research at the SAES are one-half to one-third of the size of formula funds, but two to three times the size of expenditures from cooperative grants and cooperative agreements. These other federal funds have been an important source of funds to the SAES. With some variation the current dollar expenditures increased by 129 percent from 1966 to 1979, but in constant dollars this was an overall 7 percent decline.

The major source of agricultural research funding at the SAES is the state appropriations and sales and expenditures from this source along with expenditures from private sources and formula funds from federal sources are presented in current dollars in Figure 8 and in constant dollars in Figure 9. In current dollars all three sources of funds increased during the 1966-1979 period with the state appropriations and sales increasing nearly fourfold resulting in a constant dollar increase slightly under 57 percent.

The private research funds for agricultural research at the SAES are small relative to the state appropriations and sales and the federal formula funds. Nonetheless, they have steadily increased since 1966 and are becoming an important source of agricultural research funds. During the 1966-1979 period private sources of agricultural research funds have also increased fourfold in current dollars which resulted in a constant dollar increase of 63 percent.

Private Industry Agricultural Research

Data concerning the expenditure on agricultural research by private industry are considerably more limited than data about the expenditures by the SAES and USDA. Some data concerned with applied research and development for agricultural related products obtained from the Surveys of Science Resources Series of the National Science Foundation are presented in Figure 10. The time period covered is 1963-1975. In current dollars the 1963 total expenditure by private industry for agricultural research was about $220 million and increased to slightly over $600 million in 1975 which is approximately a 170 percent increase. In constant 1967 dollars this is a 39 percent overall increase or a three percent average annual increase.

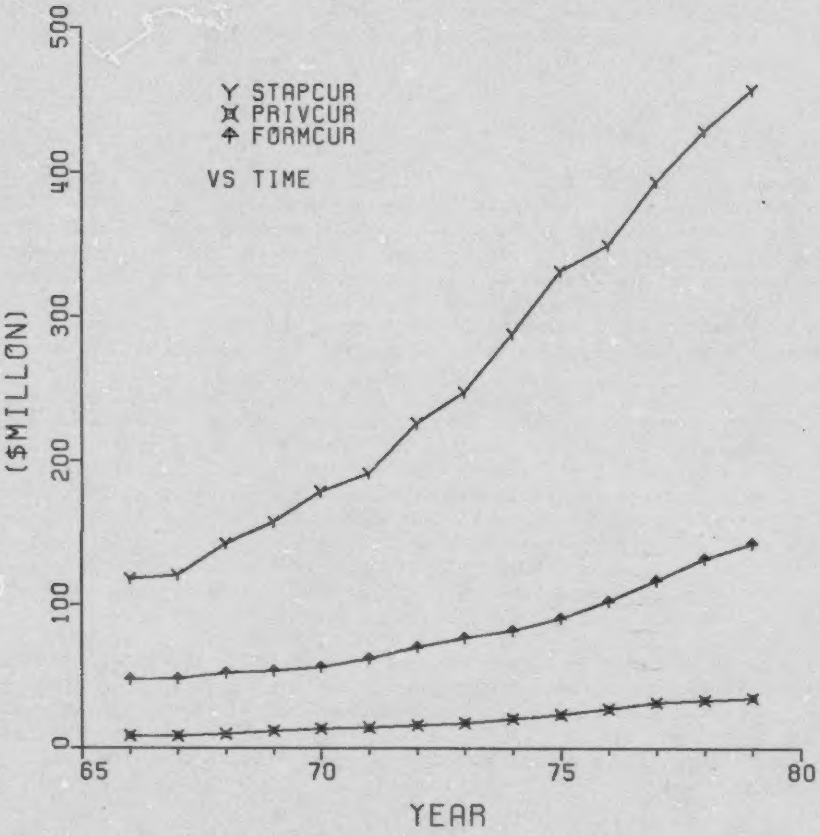
A second, even less comprehensive source of data on private agricultural research was obtained from a separate survey of agri-business firms conducted by the American Research Institute (ARI) for 1975. A summary of their information projected for the agricultural industry is presented in Table A-7. The estimated research expenditures by agricultural firms for 1975 from this survey are $575.04 million, which is slightly less than the $602 million estimated from the NSF survey for 1975. The categories from the ARI survey are not strictly compatible with those of the NSF survey so that direct comparison of PHT categories and scientist years for the two surveys are not possible. However, the similarities of the estimated overall level of private research from these two sources help substantiate the NSF figures as reasonable estimates of the level of agricultural research being conducted by private firms.

To get some perspective about relative magnitudes, in 1975 the total expenditure by private industry on applied research and development for agricultural related products was about 72 percent of the total public expenditure (SAES and USDA combined) on agricultural research. This total expenditure by private industry in 1975 was approximately 23 percent greater than the SAES's expenditure on agricultural research and about 75 percent greater than the USDA's expenditure on agricultural research.

Production, Post-Harvest Technology, and Other Food and Agricultural Research

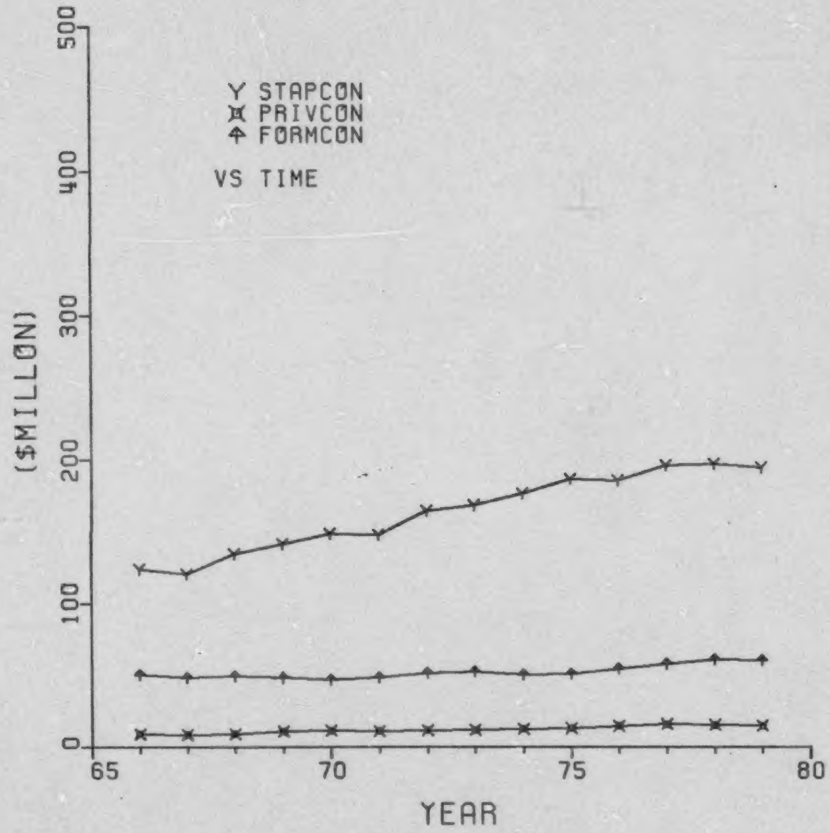
Agricultural research can be separated into three components. Production research deals with all aspects of production of crops and livestock and includes research concerned with all production activities through harvest for crops and up to the first phase of marketing for livestock. Post-harvest technology includes agricultural marketing and encompasses all functions from harvest for crops and the first phase of marketing for livestock to consumption. Thus, it includes all functions from storage to distribution of agricultural products through the institutional food trade and wholesale and retail outlets. All remaining publicly funded research

FIGURE 8. STATE APPROPRIATIONS, PRIVATE RESEARCH, AND FORMULA FUNDS AT SAES IN CURRENT DOLLARS, 1966-1979.



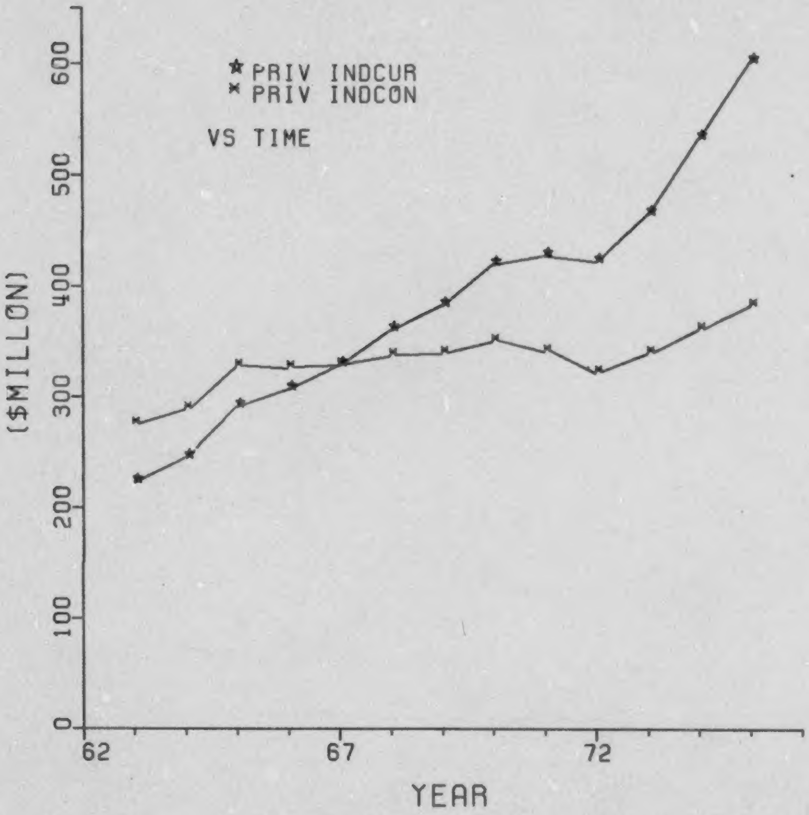
SOURCE: TABLE A-5.

FIGURE 9. STATE APPROPRIATIONS, PRIVATE RESEARCH, AND FORMULA FUNDS AT SAES IN CONSTANT DOLLARS, 1966-1979.



SOURCE: TABLE A-5.

FIGURE 10. TOTAL EXPENDITURES FOR APPLIED RESEARCH AND DEVELOPMENT FOR AGRICULTURAL RELATED PRODUCTS BY PRIVATE INDUSTRY, CURRENT AND CONSTANT DOLLARS, 1963-1975.



SOURCE: TABLE A-6.

such as rural development, human nutrition, conservation of resources, environment, etc., is classified into the other food and agricultural research category. The other category is a residual that includes all research that is neither production oriented nor post-harvest technology and agricultural marketing.

Total USDA and SAES

The combined current dollar expenditures of the USDA and SAES on post-harvest technology and agricultural marketing (PHT), production, other, and total agricultural research for the 1966-1979 period are presented in Figure 11 and the constant dollar expenditures are presented in Figure 12. Production research is a large component of total agricultural research and in both current and constant dollars exhibits patterns almost identical to those for total agricultural research. Current dollar expenditures on production research increased steadily during the 1966-1979 period for an overall increase of 215 percent which resulted in a 28 percent increase in constant dollars.

PHT accounted for about 24 percent of total agricultural research funds of the USDA and SAES in 1966 and approximately 19 percent in 1979. In current dollars the expenditures on PHT by the USDA and SAES steadily increased 143 percent from 1966 to 1979 but this overall increase resulted in a 1.5 percent overall decrease in the constant dollar expenditures.

The other food and agricultural research was the smallest of the three components and in current dollars rapidly increased from 1966 to 1978 but declined by about 20.3 million dollars from 1978 to 1979. The overall increase during the 1966-1979 period was 288 percent in current dollars and 57 percent in constant dollars.

USDA

The current dollar expenditures for PHT, production, other, and total agricultural research by the USDA for the 1966-1979 period are presented in Figure 13 and constant dollar expenditures are presented in Figure 14. The patterns are almost identical to those for the USDA and SAES combined. Production research was the largest component and expenditures increased 170 percent in current dollars from 1966 to 1979 but increased only nine percent in constant dollars.

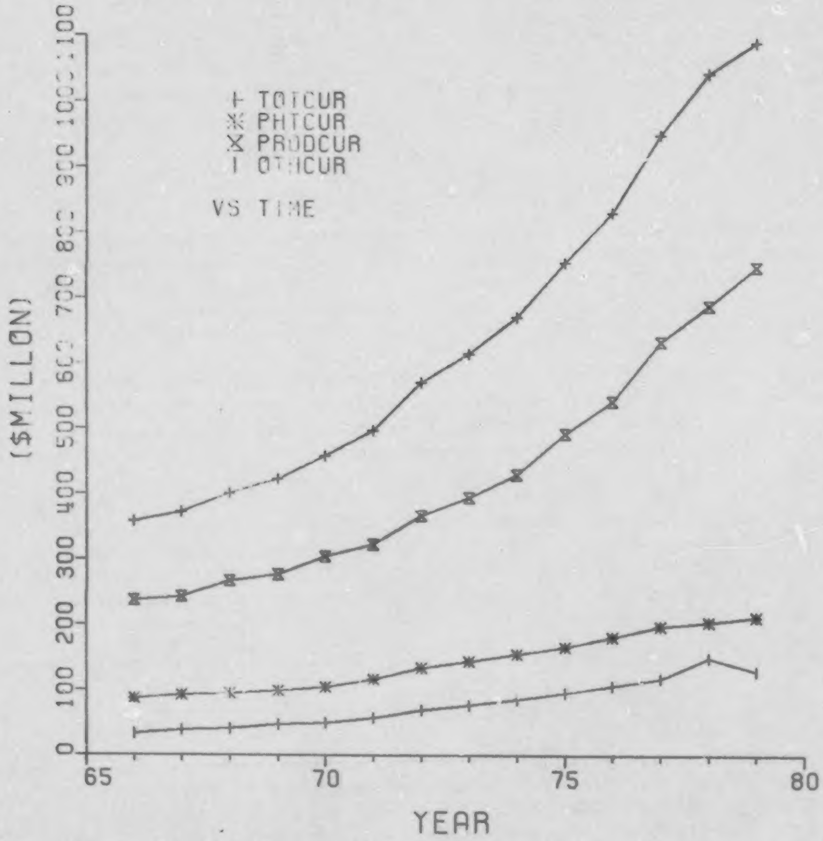
During the fourteen-year period expenditures on PHT research increased 107 percent in current dollars but decreased by 16 percent in constant dollars. Much of the decrease in constant dollar expenditures has occurred from 1977 to 1979, partly because of the level of current dollar funding but more because of the rate of inflation. As a proportion of total research expenditures, PHT ranged from 35 percent in 1966 to 29 percent in 1979.

Expenditures on other agricultural research has exhibited the greatest increase in both current and constant dollars during the fourteen-year period despite a sharp decrease in expenditures from 1978 to 1979. From 1966 to 1979 the current dollar expenditures increased 191 percent while constant dollar expenditures increased 18 percent. The other research is still a small component of total agricultural research in the USDA and in 1979 accounted for only eight percent of the total.

SAES

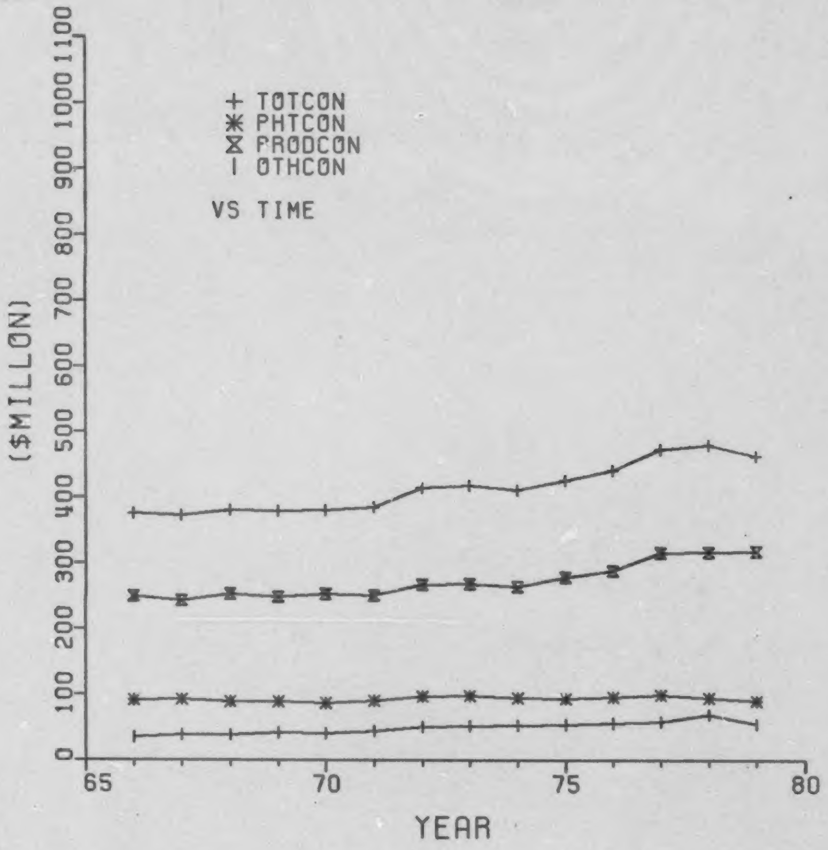
The current and constant dollar expenditures on PHT, production, other, and total agricultural research by the SAES for the 1966-1979 period are presented in Figures 15 and 16, respectively. The patterns are similar to those for the USDA. Production oriented research is the largest component and during the 1966-1979 period current dollar expenditures increased 241 percent while constant dollar expenditures increased only 23 percent. The levels of expenditures on PHT, and other research were approximately the same magnitude but current and constant dollar expenditures on other research increased 335 percent and 76 percent respectively while for PHT research the increases in current dollar expenditures was 203 percent and only 23 percent in constant dollars. The expenditures of PHT ranged from 16 percent of total agricultural research funds in 1966 to 14 percent in 1979. For other research the proportion increased from eleven percent in 1966 to 14 percent in 1979 but was as lush as 16 percent in 1978.

FIGURE 11. PHT, PRODUCTION, OTHER AND TOTAL RESEARCH EXPENDITURES AT COMBINED USDA AND SAES IN CURRENT DOLLARS, 1966-1979.



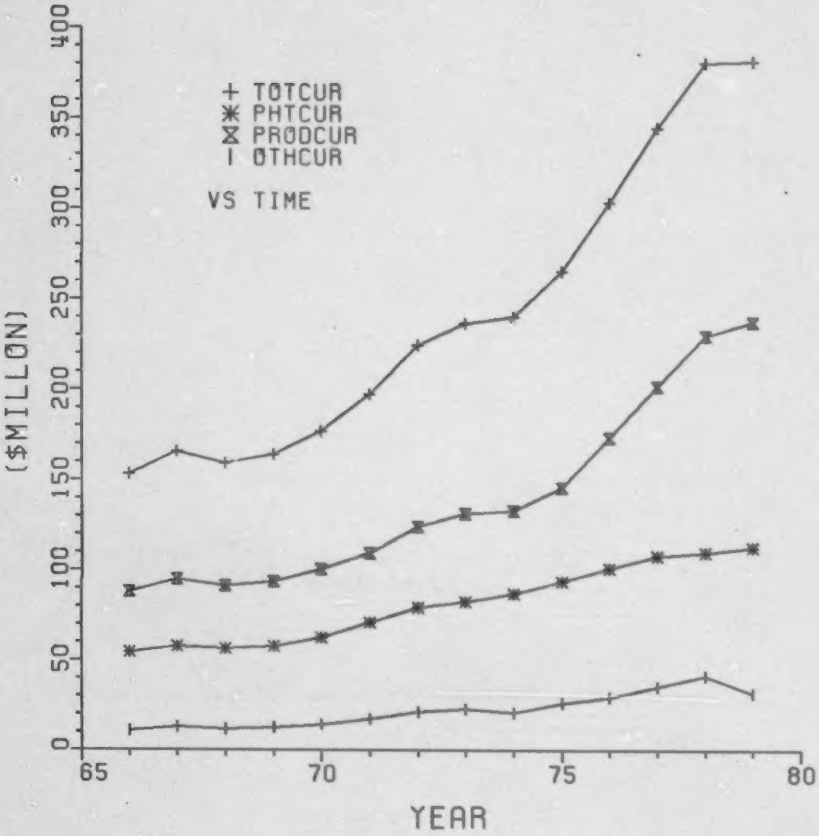
SOURCE: TABLE A-8.

FIGURE 12. PHT, PRODUCTION, OTHER AND TOTAL RESEARCH EXPENDITURES AT COMBINED USDA AND SAES IN CONSTANT DOLLARS, 1966-1979.



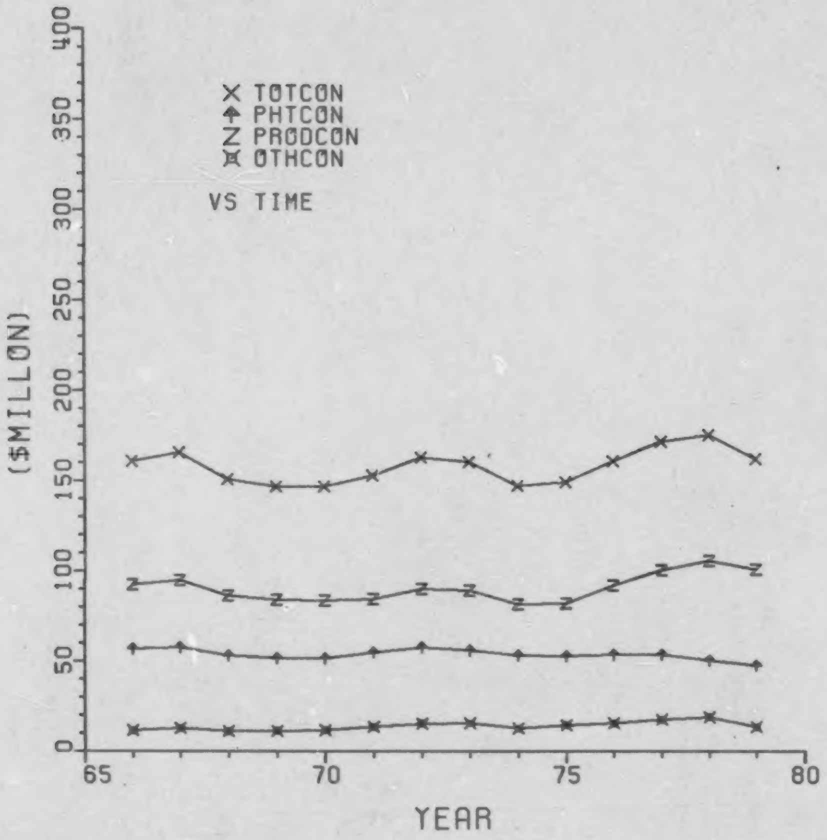
SOURCE TABLE A-8.

FIGURE 13. PHT, PRODUCTION, OTHER AND TOTAL RESEARCH FUNDS AT USDA IN CURRENT DOLLARS, 1966-1979.



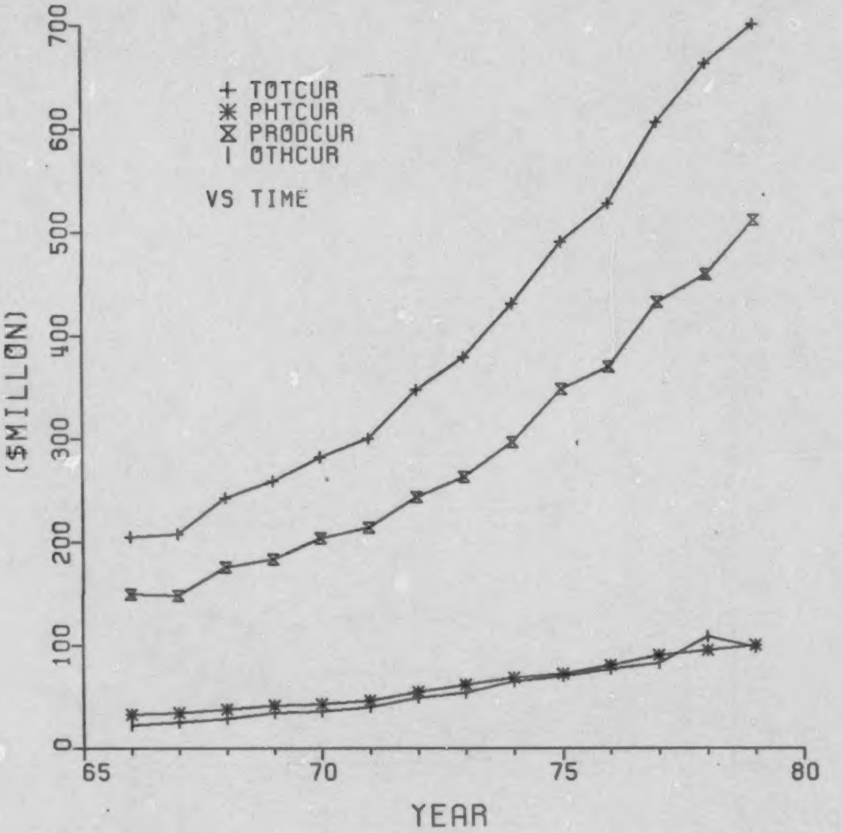
SOURCE: TABLE A-9.

FIGURE 14. PHT, PRODUCTION, OTHER AND TOTAL RESEARCH FUNDS AT USDA IN CONSTANT DOLLARS, 1966-1979.



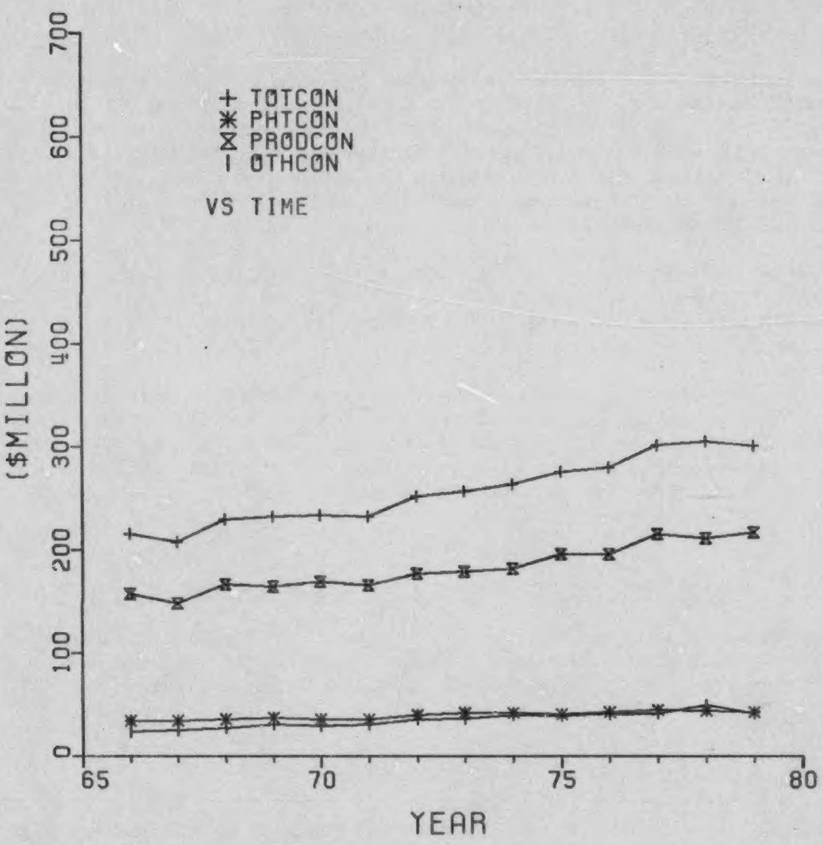
SOURCE: TABLE A-9.

FIGURE 15. PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH FUNDS AT SAES IN CURRENT DOLLARS, 1966-1979.



SOURCE: TABLE A-10.

FIGURE 16. PHT, PRODUCTION, OTHER AND TOTAL RESEARCH FUNDS AT SAES IN CONSTANT DOLLARS, 1966-1979.



SOURCE: TABLE A-10.

Private Industry

Data are not available on agricultural research expenditures by private industry to permit separating out PHT, production, and other food and agricultural research. Data available for private industry pertain to applied research and development in agricultural related products. The three major components of applied research and development for agricultural related products are applied research and development on food and kindred products, agricultural chemicals, and farm machinery. Much of the applied research and development in agricultural chemicals and farm machinery tend to be production oriented. If it is assumed that the applied research and development on food and kindred products in private industry is of similar nature to the PHT research in the public sector, then some comparisons similar to those made for PHT expenditures by the SAES and USDA may be made.

Expenditures by private industry on applied research and development on food and kindred products, agricultural chemicals, and farm machinery for the 1963-1975 period are presented in current dollars in Figure 17 and in constant dollars in Figure 18. The largest of these three and the only one exhibiting a steady increase in expenditures during this time period was the applied research and development on food and kindred products. In current dollars the expenditures increased by 186 percent from 1963 to 1975 and 47 percent in constant dollars. These expenditures accounted for nearly half of the total expenditures on applied research and development for agricultural related products.

Current dollar expenditures by private industry for applied research and development in farm machinery exhibited an erratic pattern during the 1963-1975 period but overall increased about 91 percent. Most of the erratic fluctuations occurred between 1967 and 1972. The constant dollar expenditures also exhibited considerable fluctuation with the highest constant dollar expenditure occurring in 1965. In constant dollars the applied research and development expenditures by private industry on farm machinery decreased by two percent from 1963 to 1975 and by 15 percent from the high in 1965 to 1975.

Current dollar expenditures by private industry for applied research and development on agricultural chemicals steadily increased from 1963 to 1975 except for 1972 and 1973 with the overall increase being about 267 percent. The constant dollar expenditures varied over the 1963-1975 period but overall increased about 88 percent.

Finally, in terms of relative magnitudes, the expenditures by private industry for applied research and development on food and kindred products ranged from 150 percent of the expenditures by the SAES and USDA combined on PHT research in 1966 to 1976 percent in 1975. In other words, during that ten year period the expenditures by private industry for applied research and development on food and kindred products increased more rapidly than did the expenditures by the SAES and USDA on PHT research.

Expenditures on PHT Research for Selected Commodities

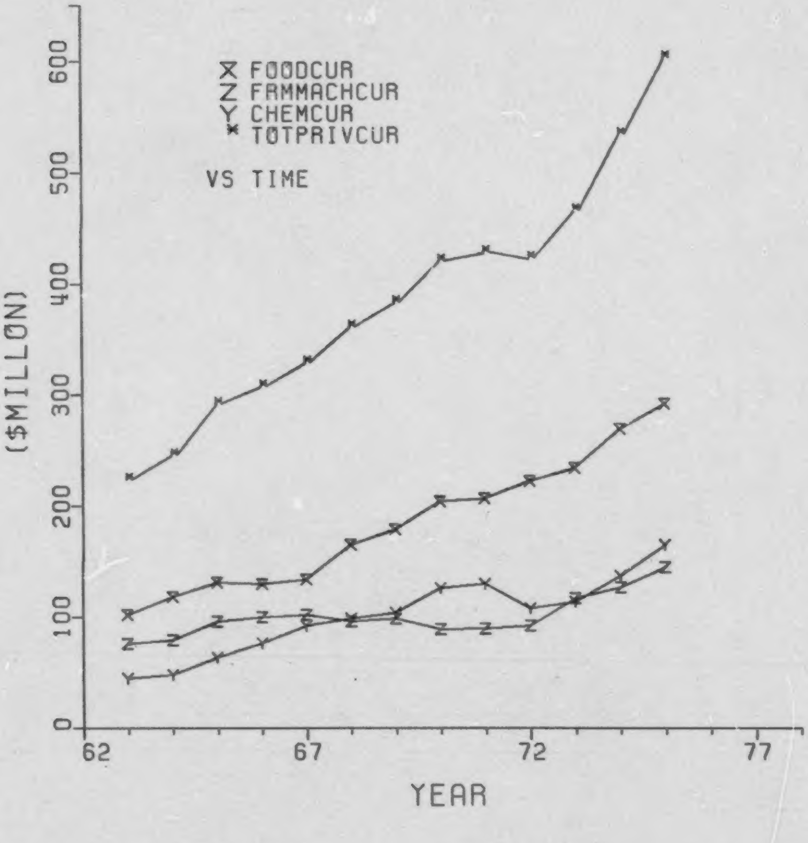
Focus in this section is on comparisons of PHT and total research expenditures by the SAES and USDA for selected commodities in order to obtain some insight into the patterns of expenditures on PHT research for various commodities. The commodities considered were selected on a judgment basis and included selected vegetables, field crops, and livestock.

Potatoes

The current dollar expenditures by the SAES and the USDA on PHT and total research on potatoes during the 1966-1979 period are presented in Figure 19 and the constant dollar expenditures are presented in Figure 20. In both the SAES and USDA the current dollar expenditures on total research on potatoes increased during the 1966-1979 period with an overall increase of 213 percent in the SAES and 112 percent in the USDA. In constant dollars the increase in the SAES was 27 percent while for the USDA the constant dollar expenditures decreased 14 percent over the fourteen-year period.

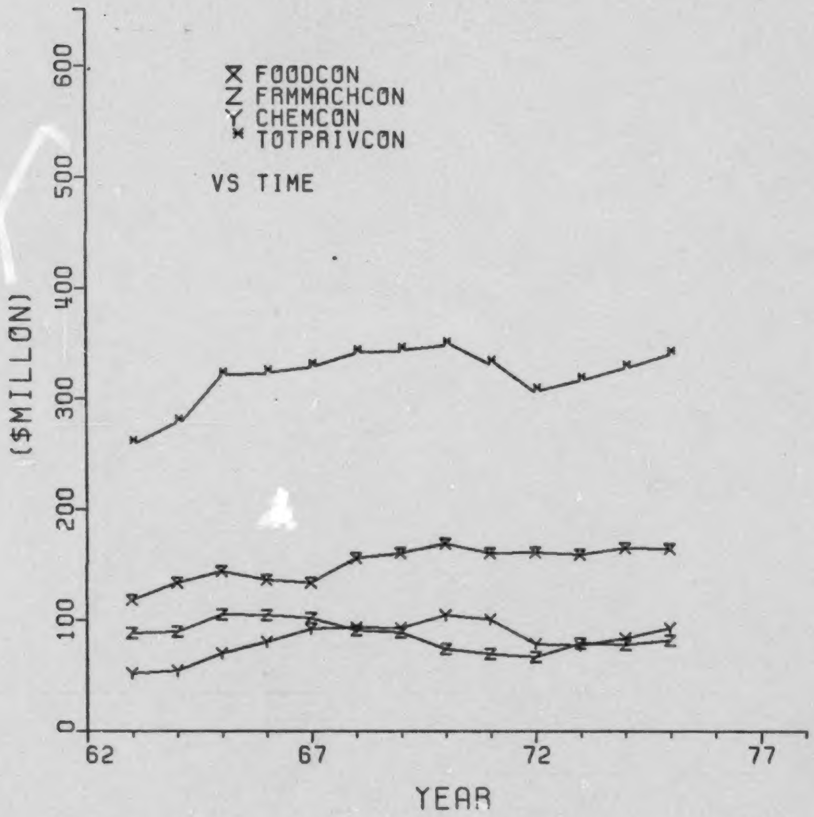
Current dollar expenditures on PHT research on potatoes varied in both the SAES and USDA during the 1966-1979 period and decreased from 1977 to 1979 in both the SAES and USDA. Over the entire fourteen-year period the current dollar expenditures on potato PHT research increased by 164 percent in the SAES and by 144 percent in the USDA. In constant dollars, the expenditures increased by seven percent in the SAES and decreased by one percent in the USDA. The percent of

FIGURE 17. APPLIED RESEARCH AND DEVELOPMENT EXPENDITURES ON FOOD AND KINDRED PRODUCTS, AGRICULTURAL CHEMICAL, AND FARM MACHINERY BY PRIVATE INDUSTRY IN CURRENT DOLLARS, 1963-1975.



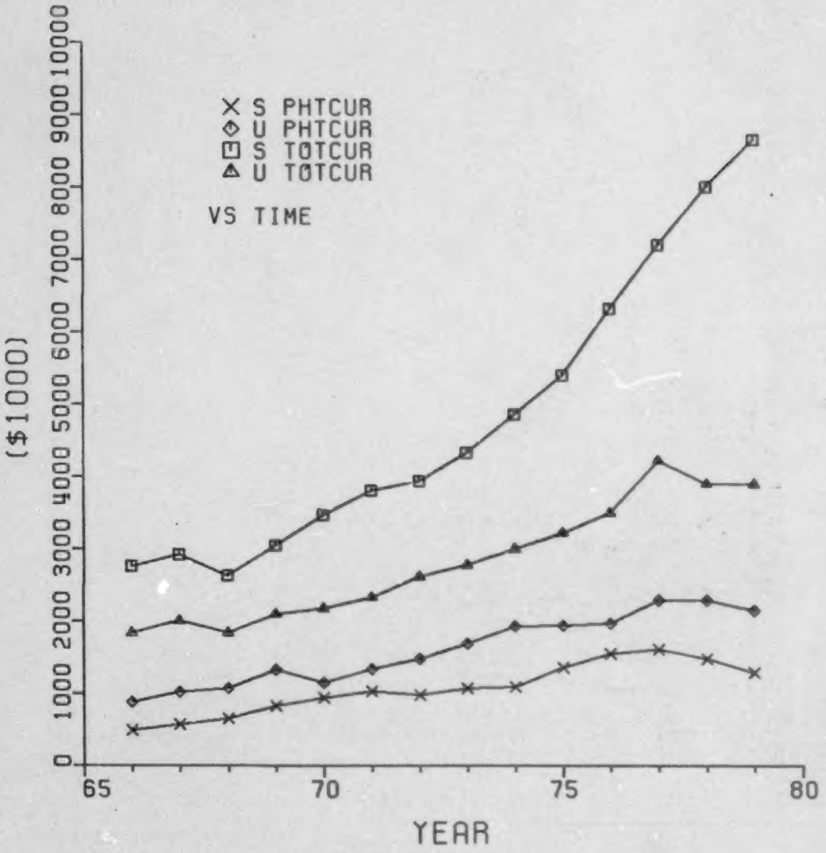
SOURCE: TABLE A-6.

FIGURE 18. APPLIED RESEARCH AND DEVELOPMENT EXPENDITURES ON FOOD AND KINDRED PRODUCTS, AGRICULTURAL CHEMICAL, AND FARM MACHINERY BY PRIVATE INDUSTRY IN CONSTANT DOLLARS, 1963-1975.



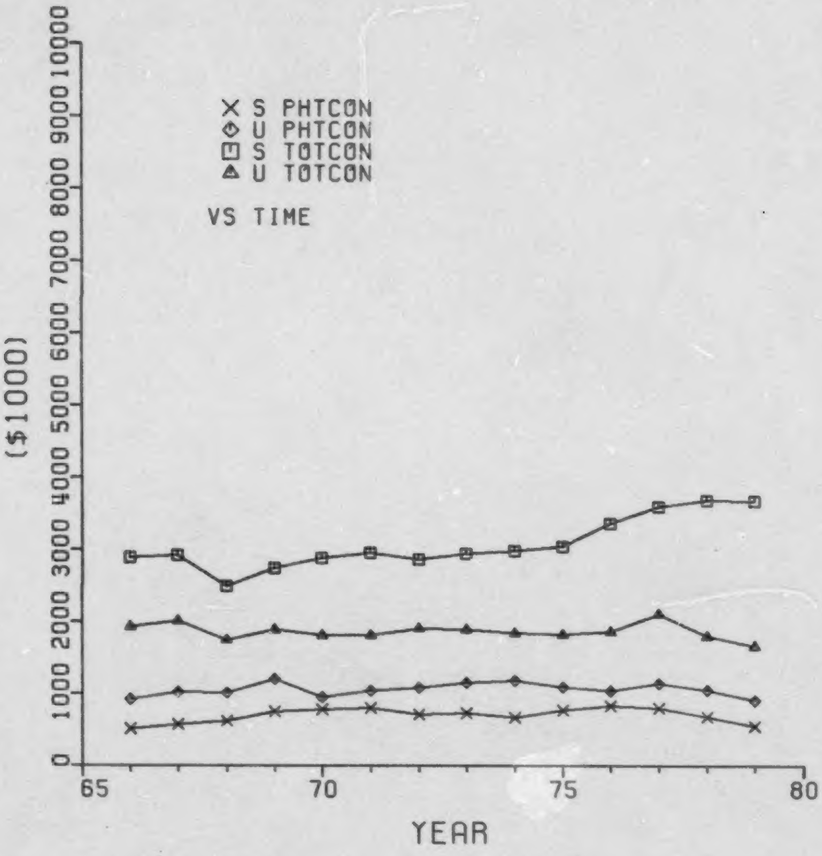
SOURCE: TABLE A-6.

FIGURE 19. POTATO PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CURRENT DOLLARS, 1966-1979.



SOURCE: TABLE A-11.

FIGURE 20. POTATO PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CONSTANT DOLLARS, 1966-1979.



SOURCE: TABLE A-11.

total research expenditures for potatoes devoted to PHT research varied in the SAES from about 27 percent in 1969-1971 to 15 percent in 1979 and in the USDA from about 63 percent in 1969 to 55 percent in 1979.

Other Vegetables

The current dollar expenditures during the 1966-1979 period by SAES and USDA on PHT and total research on vegetables other than potatoes are presented in Figure 21 and the corresponding constant dollar expenditures are in Figure 22. The amounts of funds allocated to all vegetable research were substantially greater at SAES than in the USDA and increased at a more rapid rate in the SAES. In current dollar expenditures the overall increase from 1966 to 1979 was 193 percent in the SAES and 118 percent in the USDA. The corresponding changes in constant dollar expenditures were an 18 percent increase in the SAES and a 12 percent decrease in the USDA.

In the SAES, PHT research expenditures as a percent of total research expenditures on vegetables other than potatoes reached a peak of 19 percent in 1969 and decreased to about 14 percent in 1979. From 1966 to 1979 the current dollar expenditures on PHT research on vegetables other than potatoes increased 201 percent while the increase in constant dollars was only 22 percent.

In the USDA the current dollar expenditures on PHT research on vegetables other than potatoes increased 167 percent from 1966 to 1969 and the constant dollar expenditures increased eight percent. PHT research expenditures as a percent of total research expenditures on vegetables other than potatoes ranged from a high of 54 in 1969 to a low of 42 percent in 1972 and was 51 percent in 1979.

Sorghum

Current and constant dollar expenditures on PHT and total sorghum research by the SAES and USDA during the 1966-1979 period are presented in Figures 23 and 24, respectively. Current dollar expenditures on total sorghum research during the fourteen-year period increased rapidly in the SAES and increased much less but more erratically in the USDA. The overall increase in current dollar expenditures from 1966 to 1979 was 277 percent in the SAES and 102 percent in the USDA. The corresponding constant dollar expenditures increased by 53 percent in the SAES but decreased by 18 percent in the USDA.

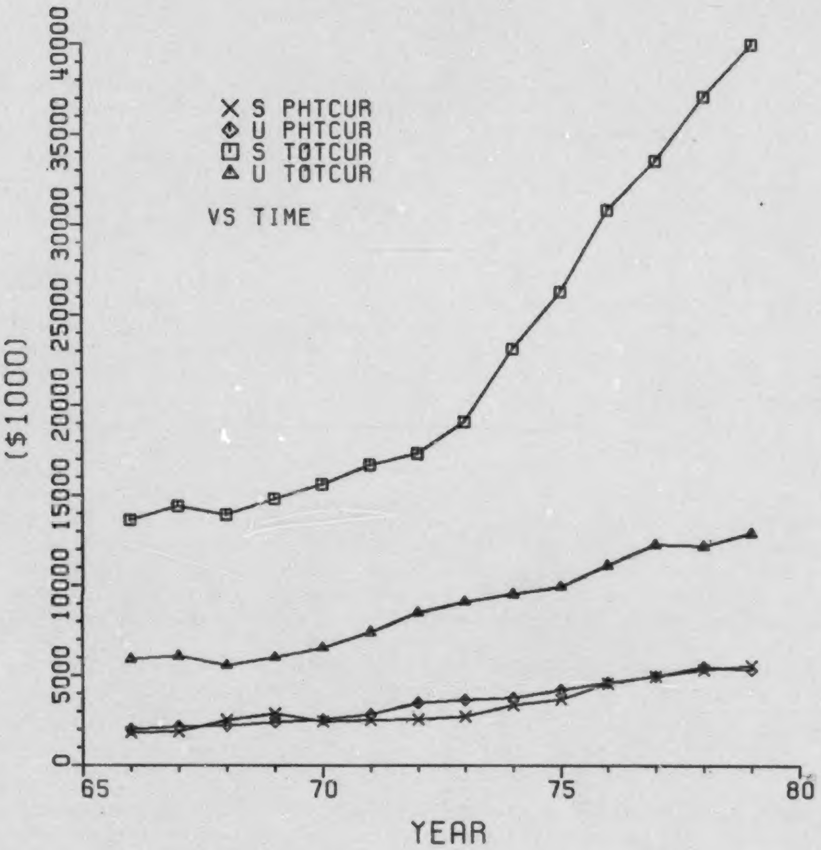
During the entire fourteen-year period the expenditures by the USDA for PHT research on sorghum were higher than the expenditures by the SAES. The current dollar expenditures for sorghum PHT research increased erratically in both the USDA and SAES with an overall increase of 149 percent in the USDA and 203 percent in the SAES. In constant dollars the increases in expenditures were only one percent by the USDA and 23 percent by the SAES. As a percent of total expenditures on sorghum research, expenditures in the USDA on sorghum PHT research ranged from a high of 71 percent in 1969 to a low of 44 percent in 1967 and 79 percent in 1979. The comparable proportions for the SAES were a high of eleven percent in 1977, a low of five percent in 1968, and nine percent in 1979.

Corn

Current and constant dollar expenditures on PHT and total research on corn by the SAES and USDA for the 1966-1979 period are presented in Figures 25 and Figure 26, respectively. The current dollar expenditures on total corn research increased 246 percent from 1966 to 1979 in the SAES and 83 percent in the USDA. In constant dollar expenditures the increase was 40 percent in the SAES but in the USDA the constant dollar expenditures decreased by 26 percent. Also, the expenditures on total corn research during the fourteen-year period fluctuated more in the USDA than in the SAES.

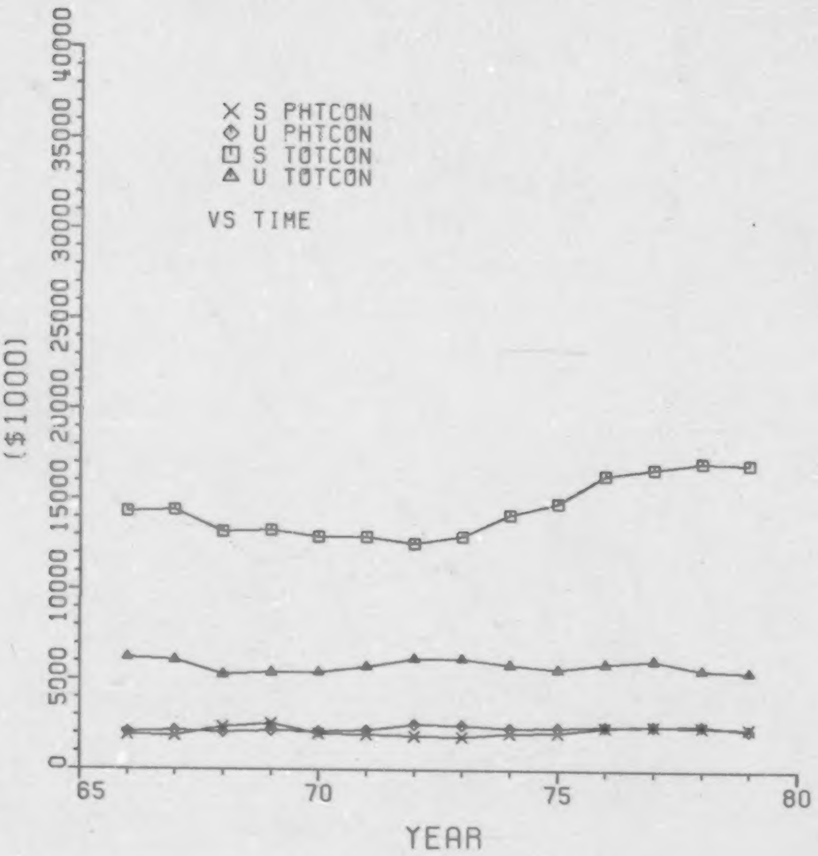
The current dollar expenditures on corn PHT research from 1966 to 1979 increased 334 percent in the SAES while the constant dollar expenditures increased 76 percent. With some minor fluctuation the increases were steady throughout the fourteen-year period. In the USDA the current dollar expenditures on corn PHT research exhibited a similar pattern but the overall increase from 1966 to 1979 was 60 percent and constant dollar expenditures declined 35 percent.

FIGURE 21. OTHER VEGETABLES PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CURRENT DOLLARS, 1966-1979.



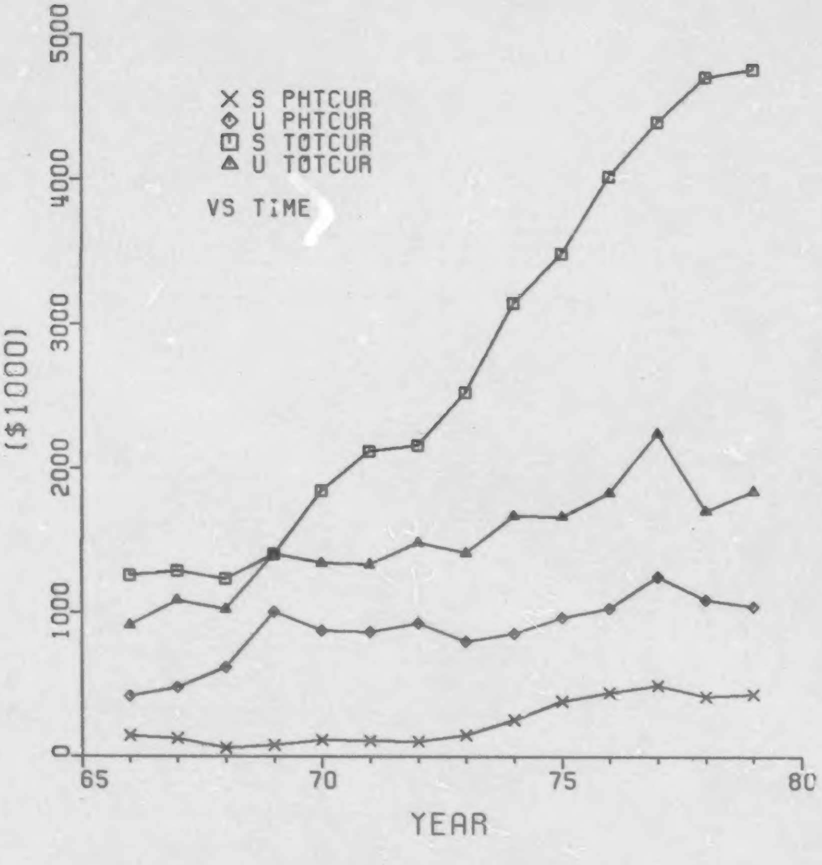
SOURCE: TABLE A-12.

FIGURE 22. OTHER VEGETABLES PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CONSTANT DOLLARS, 1966-1979.



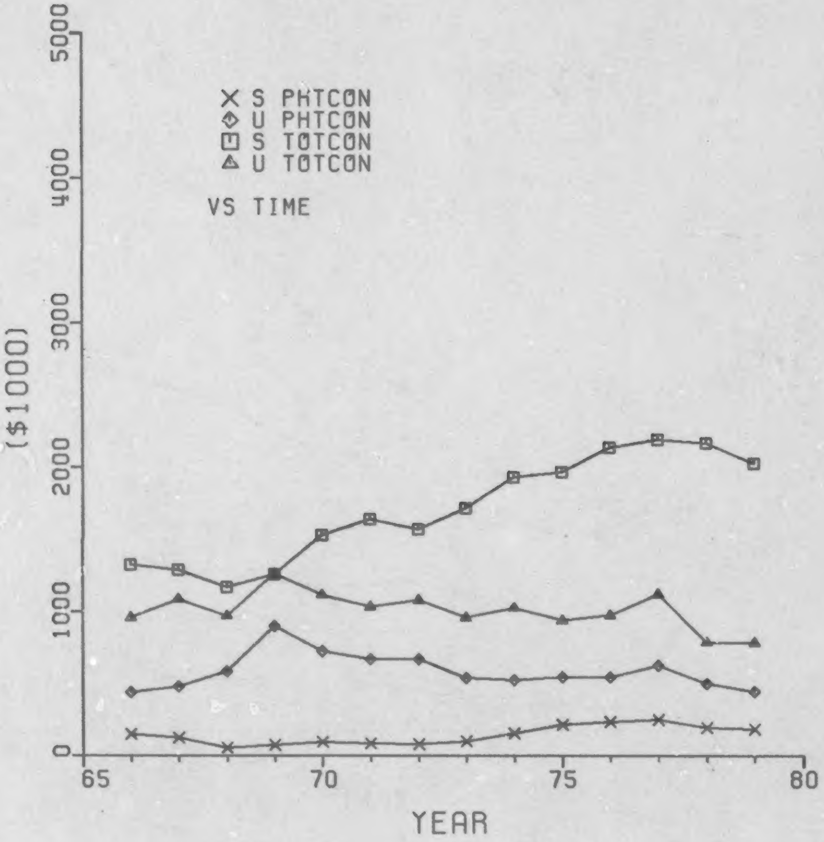
SOURCE: TABLE A-12.

FIGURE 23. SORGHUM PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CURRENT DOLLARS, 1966-1979.



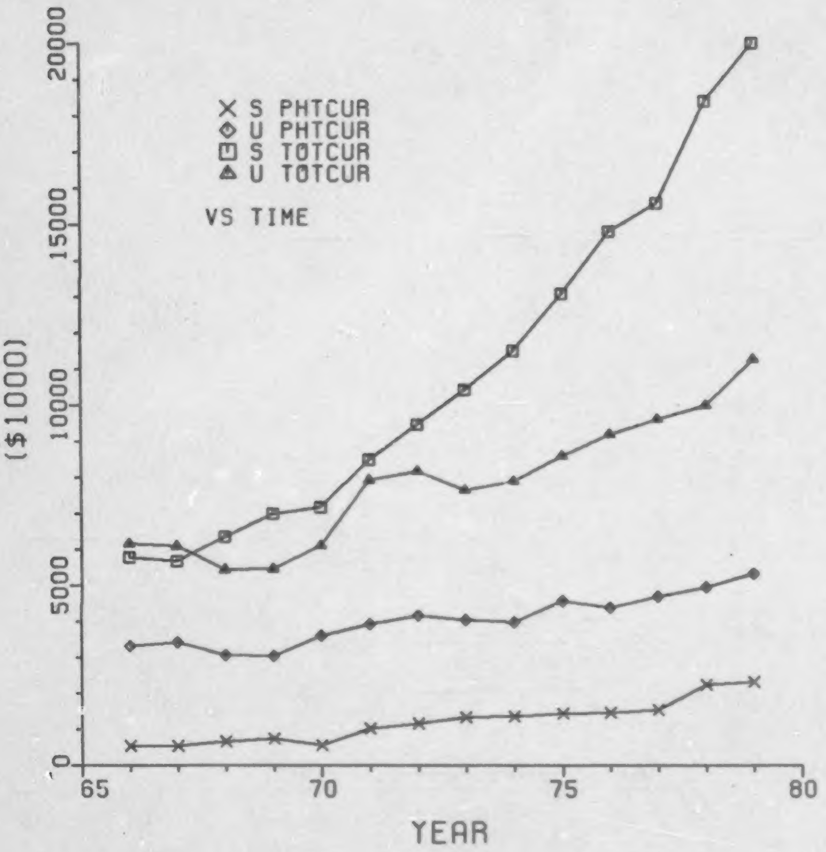
SOURCE: TABLE A-13.

FIGURE 24. SORGHUM PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CONSTANT DOLLARS, 1966-1979.



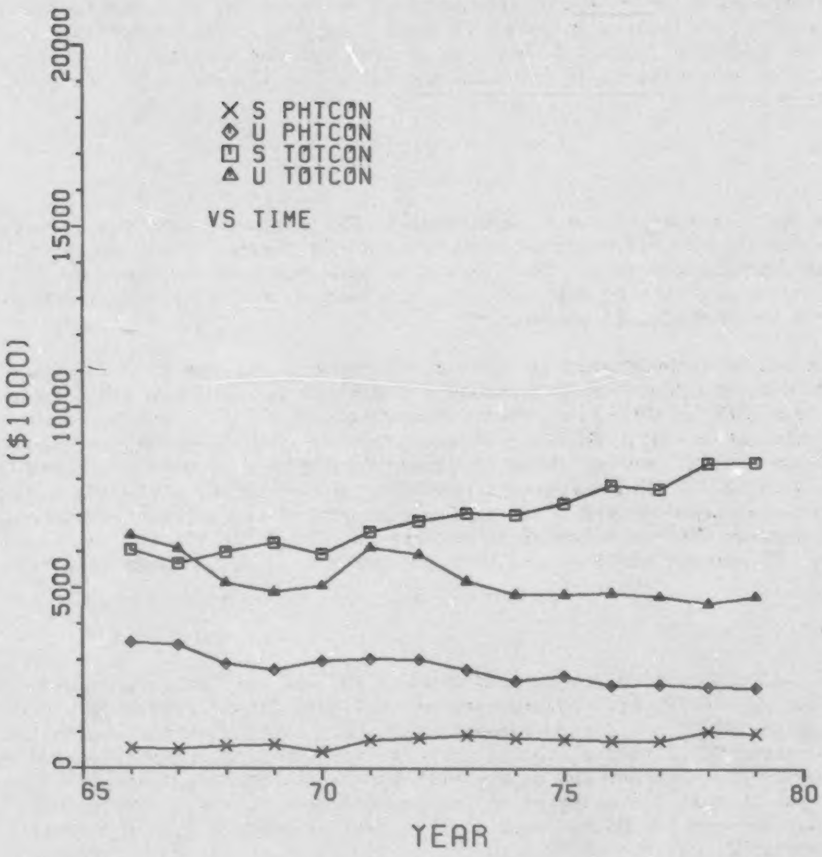
SOURCE: TABLE A-13.

FIGURE 25. CORN PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CURRENT DOLLARS, 1966-1979.



SOURCE: TABLE A-14.

FIGURE 26. CORN PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CONSTANT DOLLARS, 1966-1979.



SOURCE: TABLE A-14.

Expenditures in the SAES on PHT research as a percent of expenditures on all corn research ranged from a low of eight percent in 1970 to a high of 13 percent in 1973 and remained between ten and twelve percent to 1979. In the USDA the corresponding percent ranged from a high of 59 percent in 1970 to a low of 47 percent in 1979.

Wheat

Current and constant dollar expenditures on PHT and total research on wheat by the SAES and USDA for the 1966-1979 period are presented in Figure 27 and Figure 28, respectively. Current dollar expenditures on wheat research by the SAES increased much more rapidly than did the total expenditures by the USDA and by 1975 exceeded those by the USDA. In current dollar expenditures the overall increase from 1966 to 1979 was 250 percent in the SAES and only 27 percent in the USDA. In constant dollars the increase was 42 percent in the SAES and a decrease of 48 percent in the USDA. In 1979 the expenditure on wheat research in the SAES was 53 percent greater than that of the USDA.

Current dollar expenditures on wheat PHT research for the 1966-1979 period increased 157 percent in the SAES and 29 percent in the USDA.. In constant dollars these increases translated into a four percent increase in the SAES and a 48 percent decrease in the USDA. As a percent of total expenditures on wheat research, expenditures on wheat PHT research in the SAES ranged from a high of 22 percent in 1968 to a low of 13 percent in 1975. The proportion in 1979 was fourteen percent. In the USDA the low was 47 percent in 1966 and the high was 65 percent in 1970. In 1979 the wheat PHT expenditures in the USDA accounted for 48 percent of the total USDA expenditures on wheat research.

Soybeans

Current and constant dollar expenditures on PHT and total research on soybeans by the SAES and USDA for the 1966-1979 period are presented in Figure 29 and Figure 30, respectively. Current dollar expenditures in the SAES on all soybean research increased by 900 percent from 1966 to 1979 and in the USDA by 288 percent. In constant dollars the increase in the SAES was 306 percent and in the USDA, 57 percent.

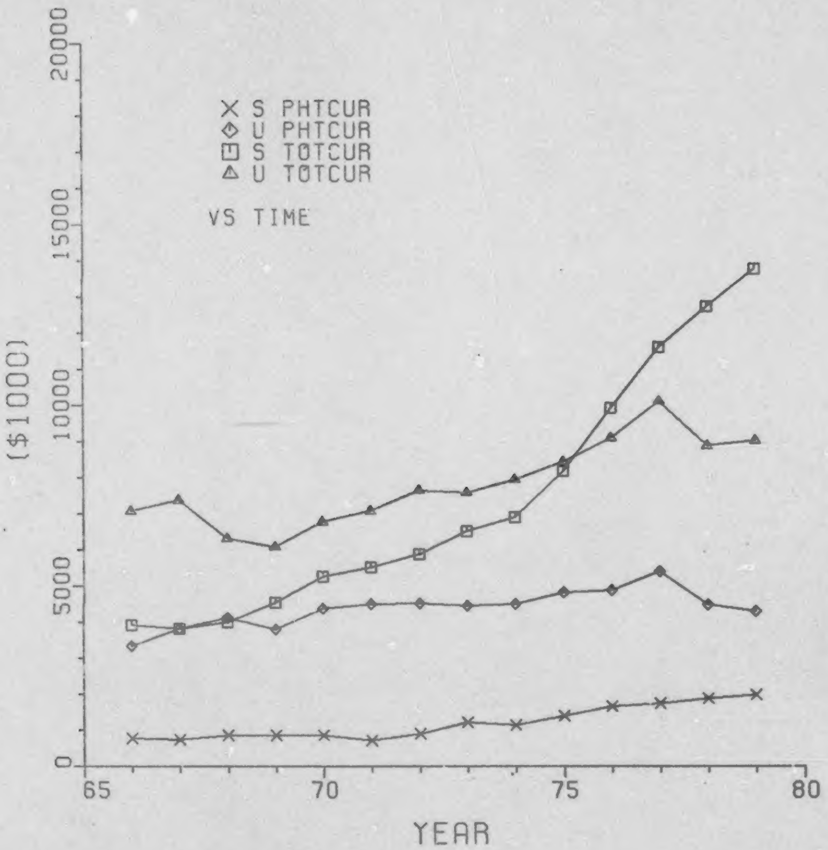
Current dollar expenditures on soybean PHT research for the 1966-1979 period increased over twelve-fold in the SAES and in constant dollars the increase was 450 percent. In the USDA the increase from 1966 to 1979 in current dollars was 182 percent, but in constant dollars this increase was only 18 percent. In the SAES expenditures on soybean PHT research as a percent of total expenditures on all soybean research ranged from a high of eleven percent in 1966 to a low of five percent in 1972. This percentage was nine percent in 1979. In the USDA expenditures on soybean PHT research as a percent of total expenditures on all soybean research ranged from a high of 71 percent in 1969 to a low of 44 percent in 1967. In 1979 the soybean PHT expenditure in the USDA was 57 percent of the total USDA expenditure on all soybean research.

Rice

Current and constant dollar expenditures on PHT and on total research on rice by the SAES and USDA for the 1966-1979 period are presented in Figure 31 and Figure 32. Current dollar expenditures in the SAES on all rice research increased by 464 percent and in the USDA by 105 percent. In constant dollars the overall increase for the fourteen-year period was 63 percent in the SAES, while the constant dollar expenditures in the USDA declined by 17 percent. From 1977 to 1979 both current and constant dollar expenditures on total rice research increased in the SAES but declined in the USDA. Much of this decline stemmed from a decrease in expenditures on rice PHT research.

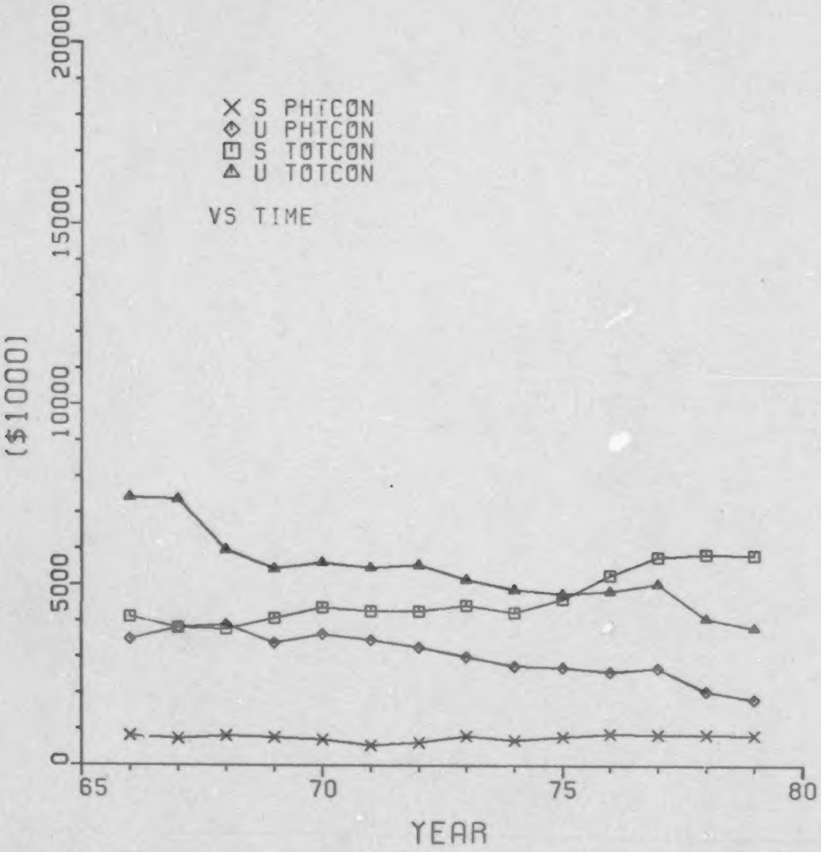
Current dollar expenditures on rice PHT research for the 1966-1979 period increased about 300 percent in the SAES while constant dollar expenditures increased 63 percent. In the USDA the increase from 1966 to 1979 was 188 percent in current dollar expenditures and 18 percent in constant dollar expenditures even with the decrease in expenditures during the last three years of the fourteen-year period. In the SAES expenditures on rice PHT research as a percent of total expenditures on all rice research ranged from a high of 13 percent in 1966 to a low of seven percent in 1970, and the proportion for 1979 was ten percent. In the USDA expenditures on rice PHT research as a proportion of total expenditures on all rice research ranged from a high

FIGURE 27. WHEAT PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CURRENT DOLLARS, 1966-1979.



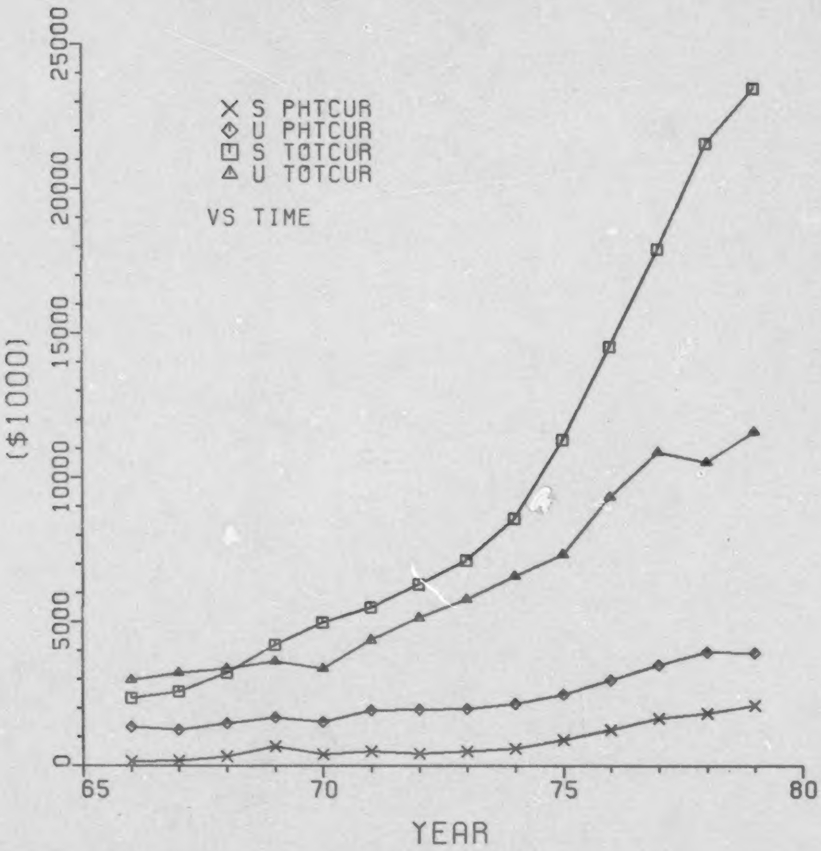
SOURCE: TABLE A-15.

FIGURE 28. WHEAT PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CONSTANT DOLLARS, 1966-1979.



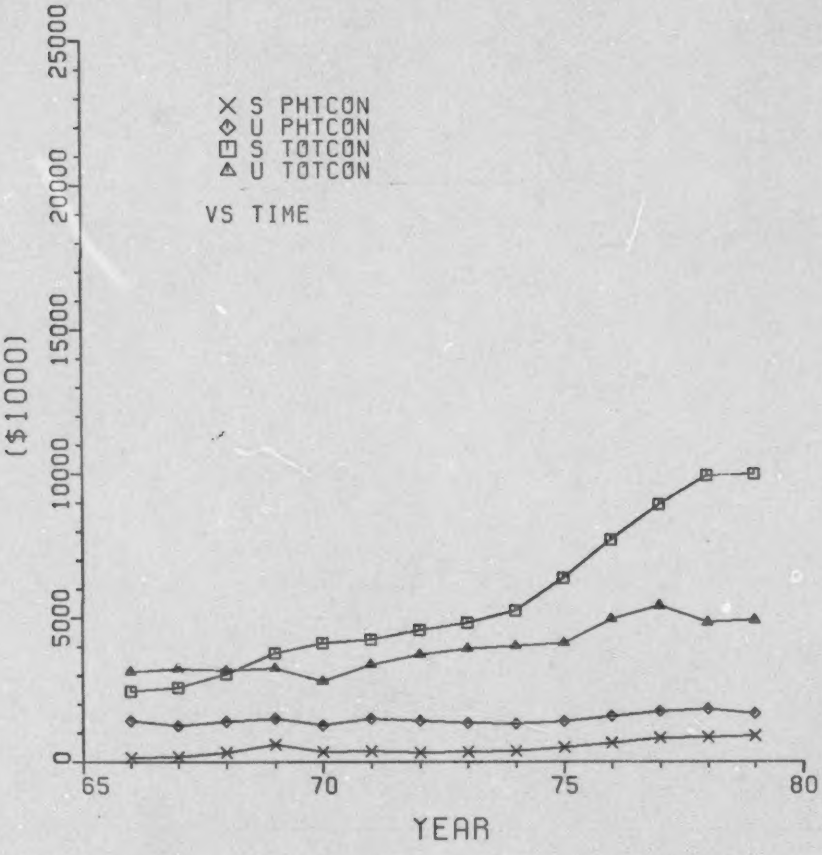
SOURCE: TABLE A-15.

FIGURE 29. SOYBEAN PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CURRENT DOLLARS, 1966-1979.



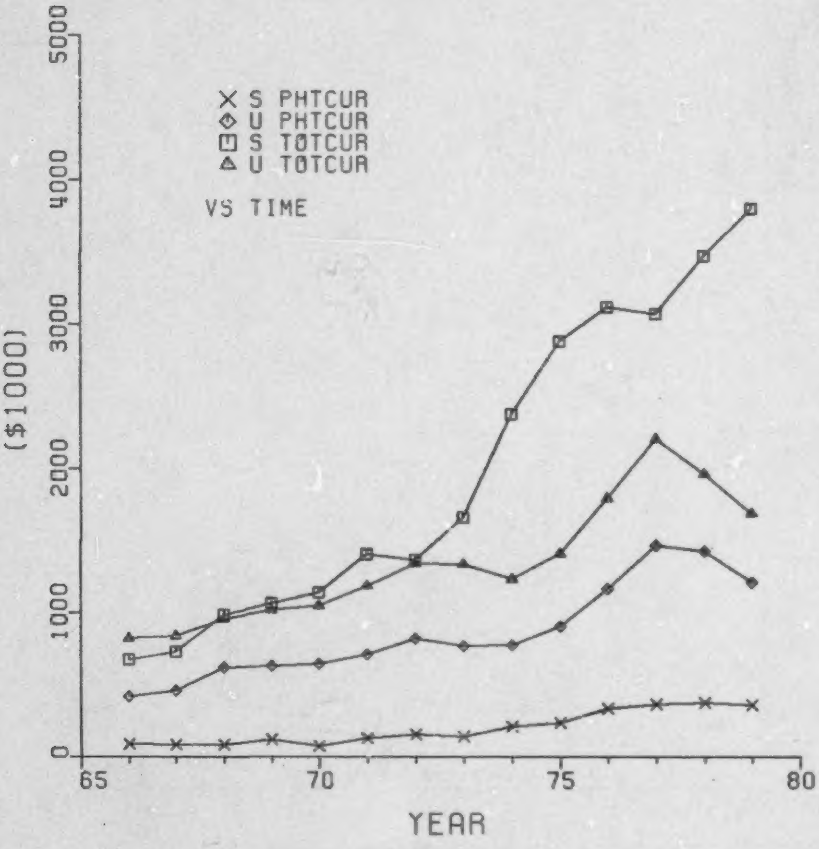
SOURCE: TABLE A-16.

FIGURE 30. SOYBEAN PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CONSTANT DOLLARS, 1966-1979.



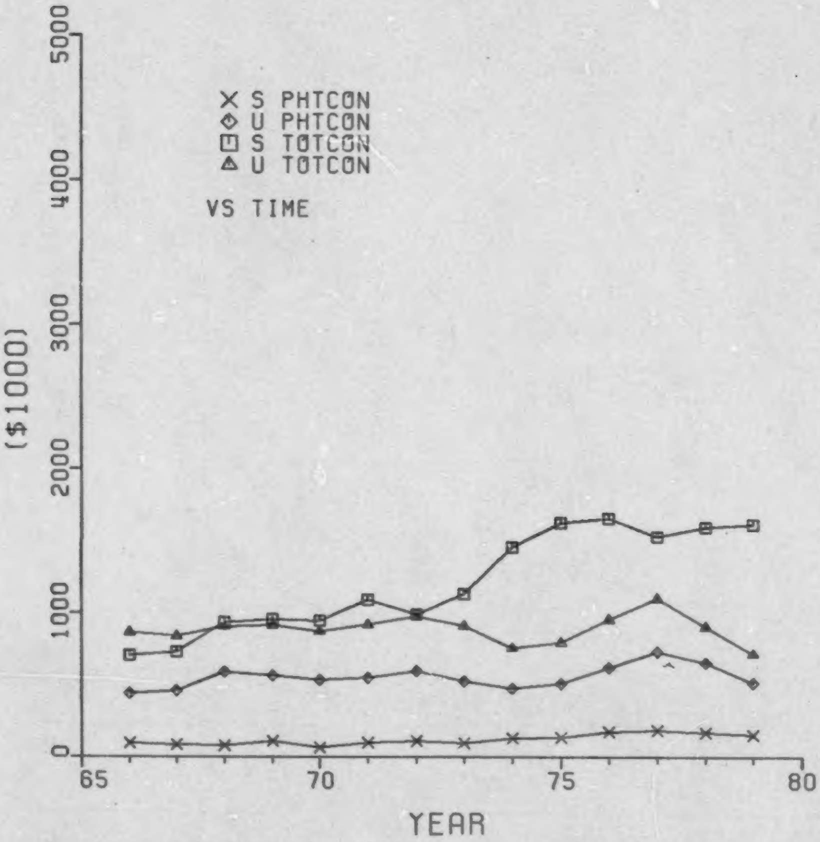
SOURCE: TABLE A-16.

FIGURE 31. RICE PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CURRENT DOLLARS, 1966-1979.



SOURCE: TABLE A-17.

FIGURE 32. RICE PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CONSTANT DOLLARS, 1966-1979.



SOURCE: TABLE A-17.

of 73 percent in 1978 to a low of 51 percent in 1966. The 1979 proportion for the USDA was about 72 percent.

Small Grains

Small grains include grains such as oats, barley, rye, millet, rape, etc. The current and constant dollar expenditures on these grains by the SAES and USDA for the 1966-1979 period are presented in Figure 33 and Figure 34, respectively. Current dollar expenditures in the SAES on all other small grain research increased by 173 percent from 1966 to 1979 and by 100 percent in the USDA. In constant dollars the increase in the SAES was only eleven percent, while in the USDA the constant dollar expenditures declined by nineteen percent.

In both the SAES and the USDA the current and constant dollar expenditures on other small grain PHT research increased dramatically from 1966 to 1979. In the SAES the increase in current dollars was 348 percent and 82 percent in constant dollars. In the USDA the increase in current dollars was 1076 percent and 377 percent in constant dollars. However, the dollar amounts are relatively small; in current dollars the increase was less than a million dollars in the USDA and was slightly over a million dollars in the SAES. In constant dollars the increase was less than half a million dollars in each. Expenditures on PHT research as a percent of total expenditures on other small grain research ranged from a low of four percent in 1972 to a high of fourteen percent in 1979 in the SAES and from a low of six percent in 1966 to a high of 35 percent in 1979 in the USDA. The proportion spent on other small grain PHT research has been increasing in both the SAES and USDA, but the amount of funds involved are relatively small.

Cotton

The SAES and USDA PHT and total research expenditures on cotton for the 1966-1979 period in current and constant dollars are presented in Figure 35 and Figure 36, respectively. For all commodities discussed thus far the total expenditures in current dollars by the SAES exceeded those by the USDA. However, this is not true for cotton. The total expenditures on cotton research by the USDA were approximately 75 percent greater than those by the SAES.

The expenditures by the USDA on cotton research increased 88 percent in current dollars from 1966 to 1969, but the constant dollar expenditures decreased by 24 percent. In the SAES the current dollar expenditures increased by 85 percent from 1966 to 1979, while the constant dollar expenditures decreased by 25 percent.

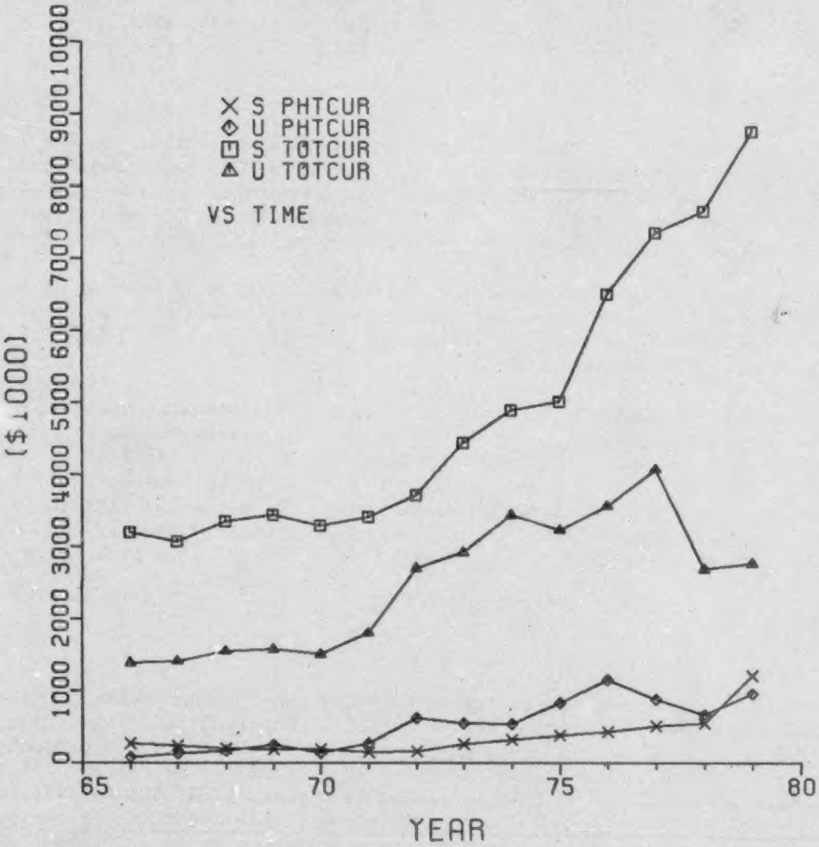
Current dollar expenditures in the USDA on cotton PHT research varied considerably over the 1966-1979 period and increased only thirteen percent. The corresponding constant dollar expenditures declined by 54 percent. In the SAES the increase in current dollars on cotton PHT research for the 1966-1979 period was 22 percent, while the corresponding constant dollar expenditures declined 50 percent. In the USDA expenditures on cotton PHT research relative to total expenditures on cotton research ranged from a high of 44 percent in 1970 to a low of 26 percent in 1979. In the SAES the corresponding proportions ranged from a high of five percent in 1968 to a low of three percent in 1979.

Cotton Seed

The current and constant dollar expenditures by the USDA and SAES on PHT and all cotton seed research for the 1966-1979 period are presented in Figure 37 and Figure 38, respectively. Most of the funding of cotton seed research was through the USDA and the expenditures in the USDA ranged from four to twenty times the expenditures in the SAES. The current dollar expenditures on all cotton seed research in the USDA increased 51 percent from 1966 to 1979, but the corresponding constant dollar expenditures declined 39 percent. In the SAES the current dollar expenditures on all cotton seed research declined six percent from 1966 to 1979 and the constant dollar expenditures declined 66 percent.

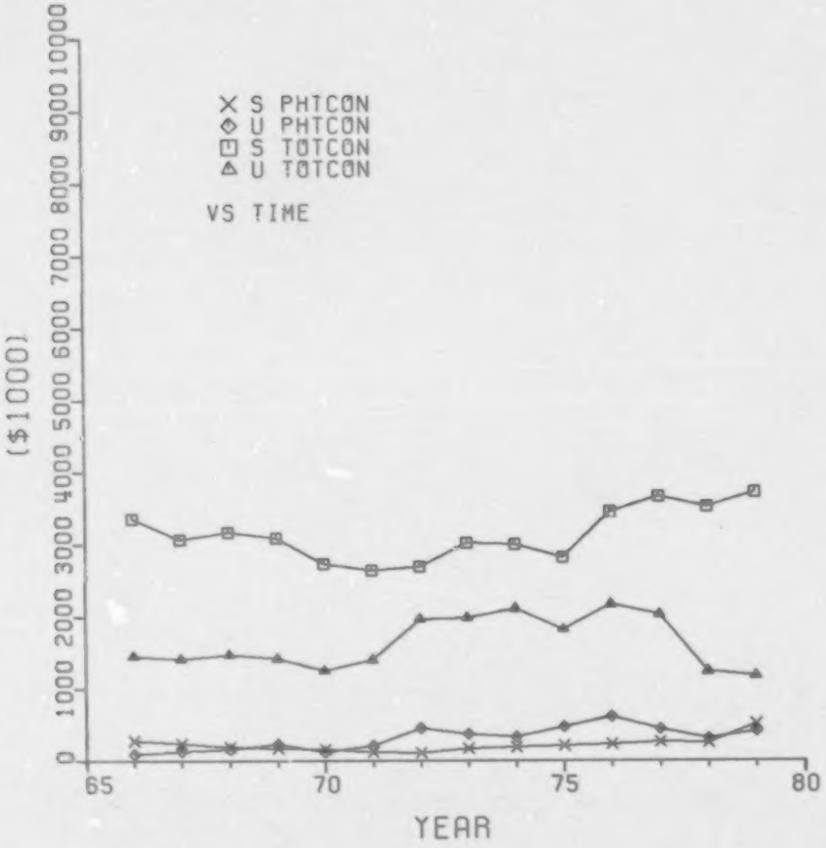
Current dollar expenditures in the USDA on cotton seed PHT research increased 110 percent from 1966 to 1979 but constant dollar expenditures declined fifteen percent. For the same period the current dollar expenditures on cotton PHT research in the SAES increased 26 percent and the constant dollar expenditures declined 49 percent. In the USDA expenditures on cotton seed PHT research as a proportion of expenditures on all cotton seed research ranged from a low of 64 percent in 1966 to a high of 93 percent in 1970. In 1979 the proportion was 89 percent. In the

FIGURE 33. SMALL GRAINS PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CURRENT DOLLARS, 1966-1979.



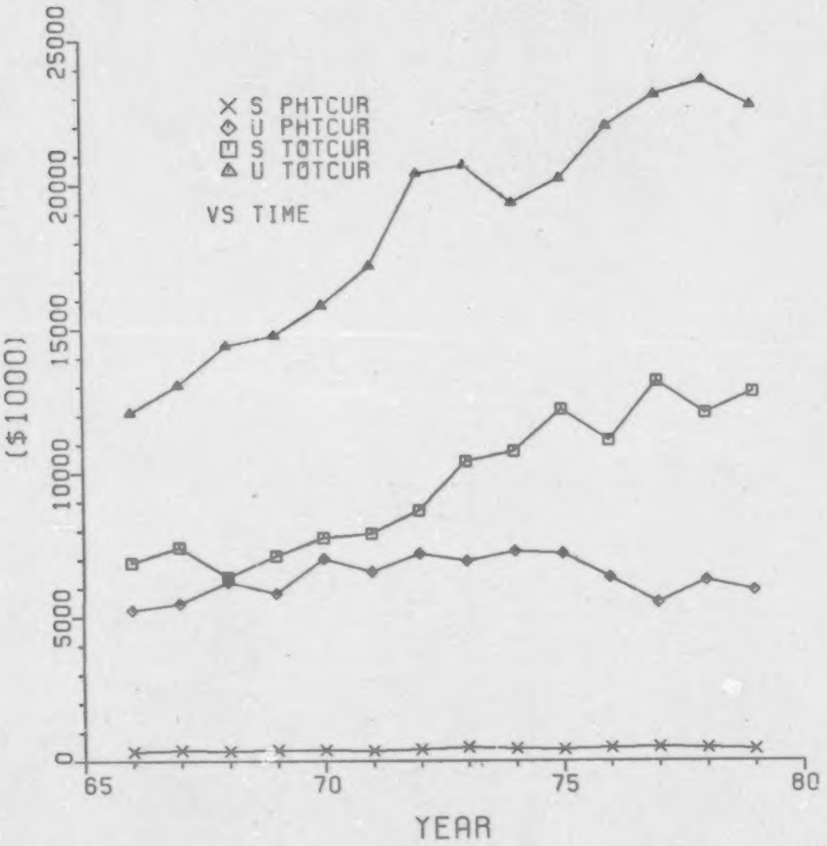
SOURCE: TABLE A-18.

FIGURE 34. SMALL GRAINS PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CONSTANT DOLLARS, 1966-1979.



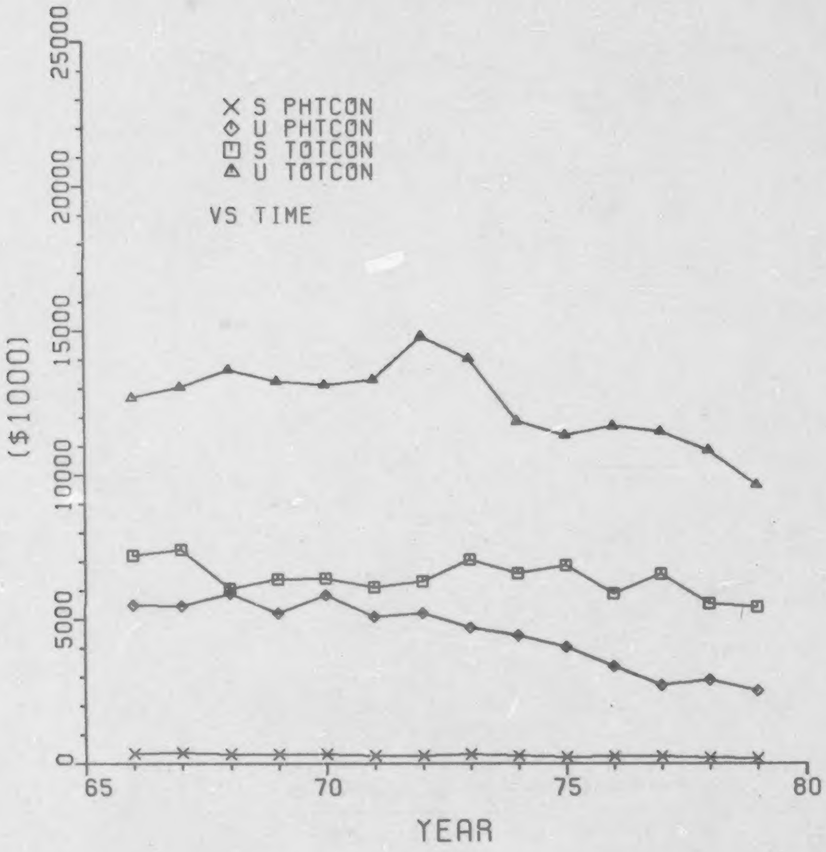
SOURCE: TABLE A-18.

FIGURE 35. COTTON PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CURRENT DOLLARS, 1966-1979.



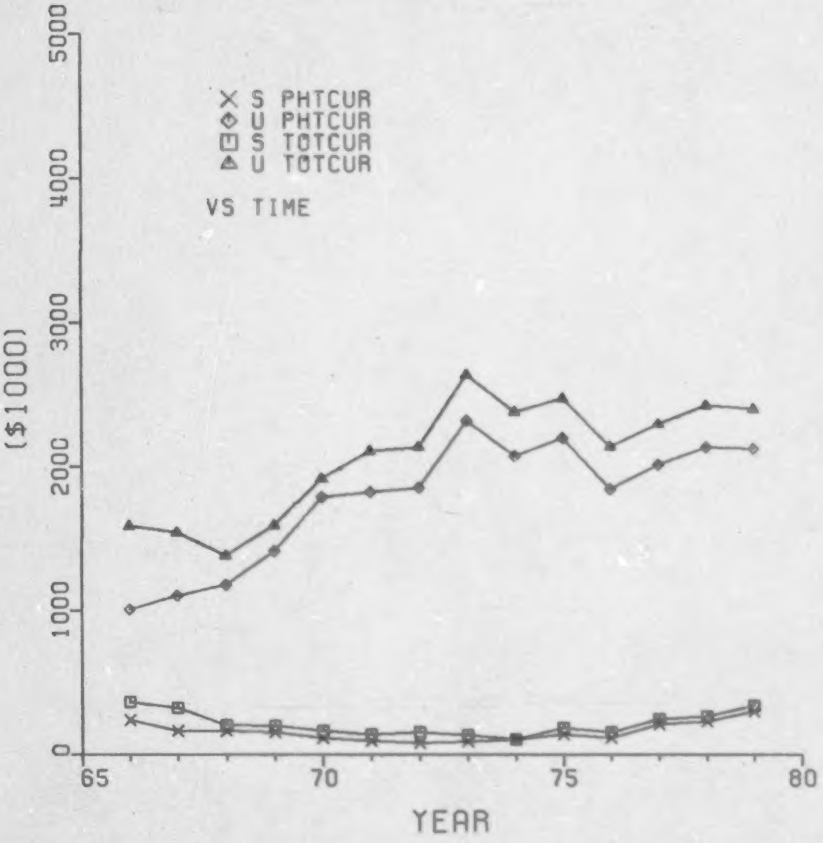
SOURCE: TABLE A-19.

FIGURE 36. COTTON PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CONSTANT DOLLARS, 1966-1979.



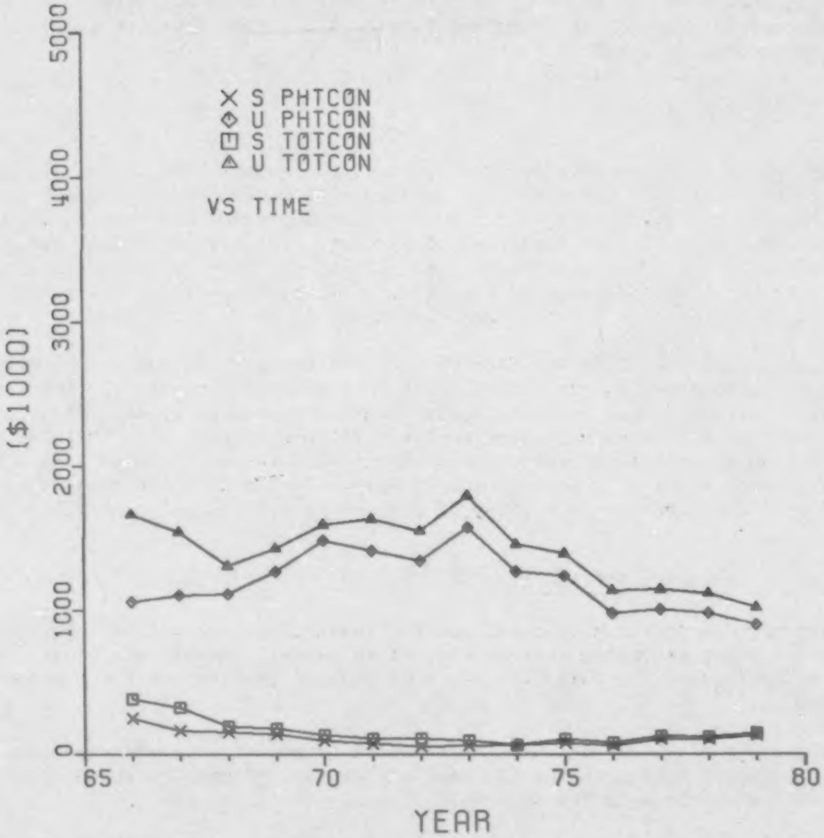
SOURCE: TABLE A-19.

FIGURE 37. COTTON SEED PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CURRENT DOLLARS, 1966-1979.



SOURCE: TABLE A-20.

FIGURE 38. COTTON SEED PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CONSTANT DOLLARS, 1966-1979.



SOURCE: TABLE A-20.

SAES the corresponding proportions range from a low of 51 percent in both 1967 and 1972 to a high of 100 percent in 1974. In 1979 expenditures on cotton seed PHT research were 88 percent of expenditures on all cotton seed research in the SAES.

Dairy

Current and constant dollar expenditures by the SAES and the USDA on PHT and all dairy research for the 1966-1979 period are presented in Figure 39 and Figure 40, respectively. Current dollar expenditures on all dairy research in the SAES increased 128 percent from 1966 to 1979, while the constant dollar expenditures decreased eight percent. The current dollar expenditures in the USDA increased 80 percent, but the constant dollar expenditures for the same fourteen-year period declined 27 percent. The total expenditures in the SAES on all dairy research during the 1966-1979 period were from 74 percent to approximately 163 percent greater than the expenditures in the USDA.

Current dollar expenditures in the SAES on dairy PHT research, which includes marketing research, increased 123 percent from 1966 to 1979 but constant dollar expenditures declined ten percent. For the same period the current dollar expenditures on dairy PHT research in the USDA increased 39 percent, while constant dollar expenditures declined 44 percent. In the SAES expenditures on dairy PHT research as a percent of expenditures on all dairy research ranged from a high of 22 percent in 1970 to a low of 17 percent in 1973 and were 18 percent in 1979. In the USDA the comparable percentages for the fourteen-year period ranged from a high of 37 percent in 1972 to a low of 18 percent in 1979.

Beef

Current and constant dollar expenditures by the SAES and the USDA on PHT and all beef research for the 1966-1979 period are presented in Figure 41 and Figure 42, respectively. Current dollar expenditures for all beef research in the SAES increased 233 percent from 1966 to 1979 and constant dollar expenditures increased 35 percent. The current dollar expenditures in the USDA increased 131 percent, but the constant dollar expenditures declined six percent. Similar to dairy, the total expenditures in the SAES on all beef research during the 1966-1979 period were from 63 to 157 percent greater than the expenditures in the USDA.

Current dollar expenditures in the SAES on beef PHT research increased 136 percent from 1966 to 1979, while the constant dollar expenditures increased 36 percent. During the same fourteen-year period current dollar expenditures on beef PHT research in the USDA increased 110 percent, but the constant dollar expenditures declined fifteen percent. In the SAES expenditures on beef PHT research as a percent of expenditures on all beef research ranged from a high of twelve percent in 1968 to a low of eight percent in 1979. In the USDA the comparable percentages for the 1966-1979 period ranged from a high of 33 percent in 1969 to a low of 21 percent in 1979.

Concluding Comments on Commodity PHT Research

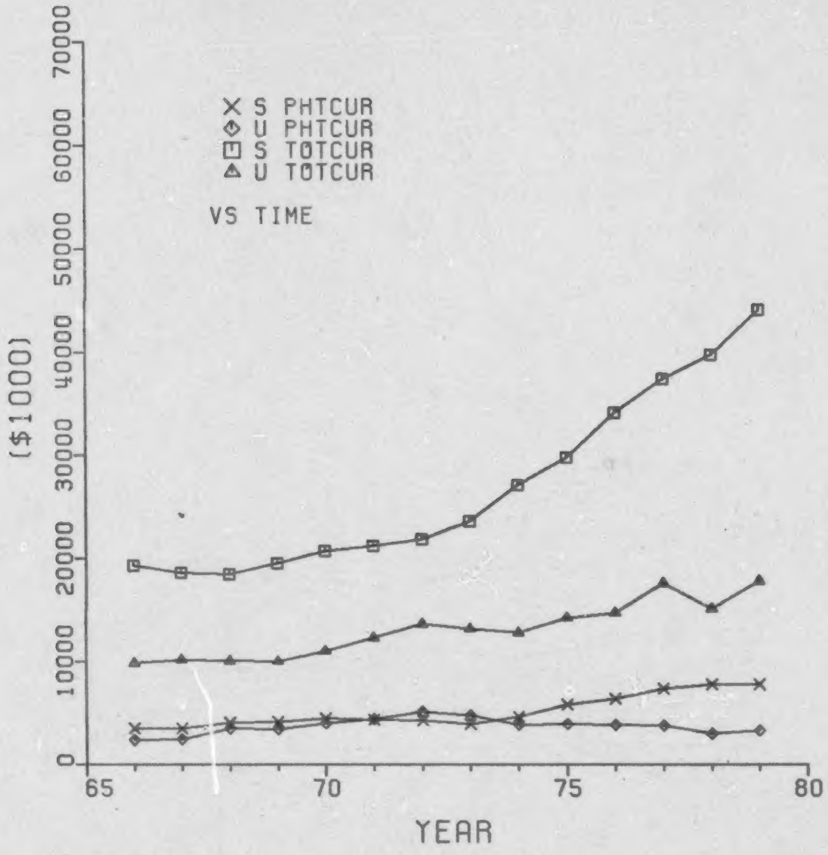
Although expenditure patterns of total and PHT research on individual commodities by the SAES and USDA exhibit numerous unique characteristics in terms of levels of funding and increases and decreases of expenditures, the following are some general conclusions abour expenditures on PHT and total research.

1. In general the total expenditures on research of specific commodities were greater in the SAES than in the USDA. Cotton and cotton seed are two exceptions for which expenditures in the USDA were greater than those in the SAES.

2. Current dollar research expenditures by both the SAES and the USDA for a commodity increased from 1966 to 1979, but the constant dollar expenditures exhibited very slight or no increases and for some commodities declined rather substantially.

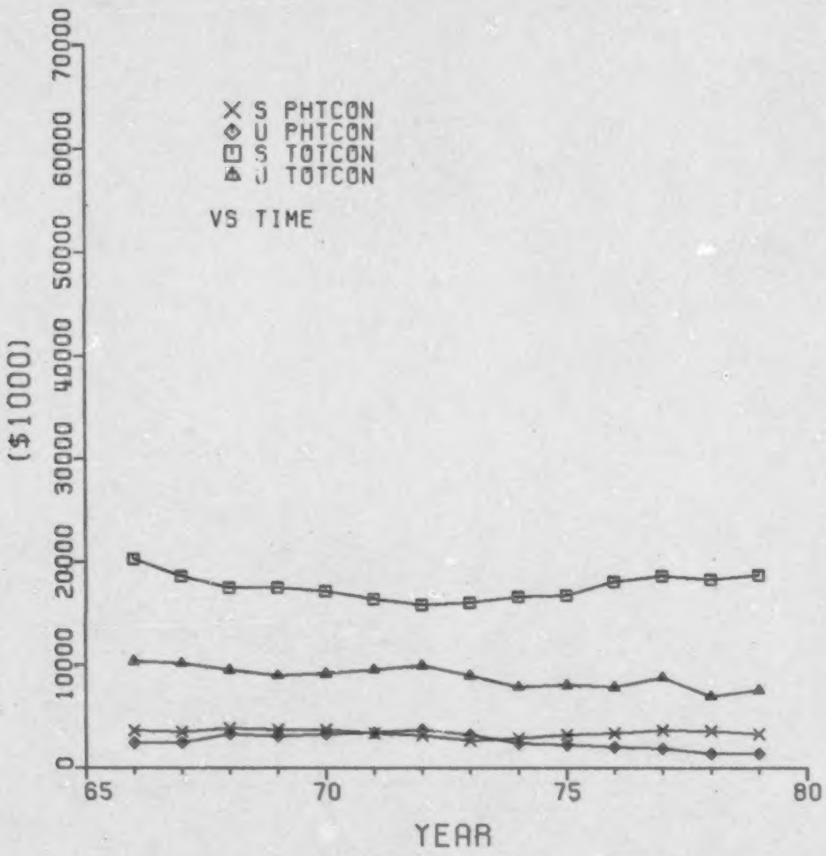
3. The loss of purchasing power during the 1966-1979 period because of inflation was very substantial, and the real dollars available for agricultural research in both the SAES and the USDA remained at about the same level over the fourteen-year period.

FIGURE 39. DAIRY PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CURRENT DOLLARS, 1966-1979.



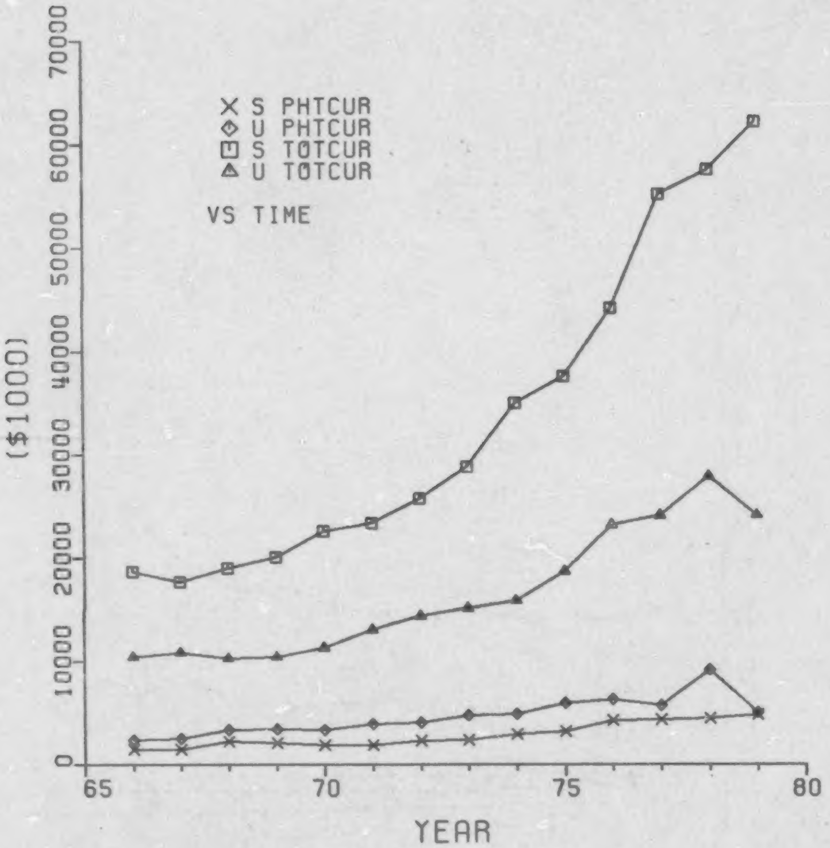
SOURCE: TABLE A-21.

FIGURE 40. DAIRY PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CONSTANT DOLLARS, 1966-1979.



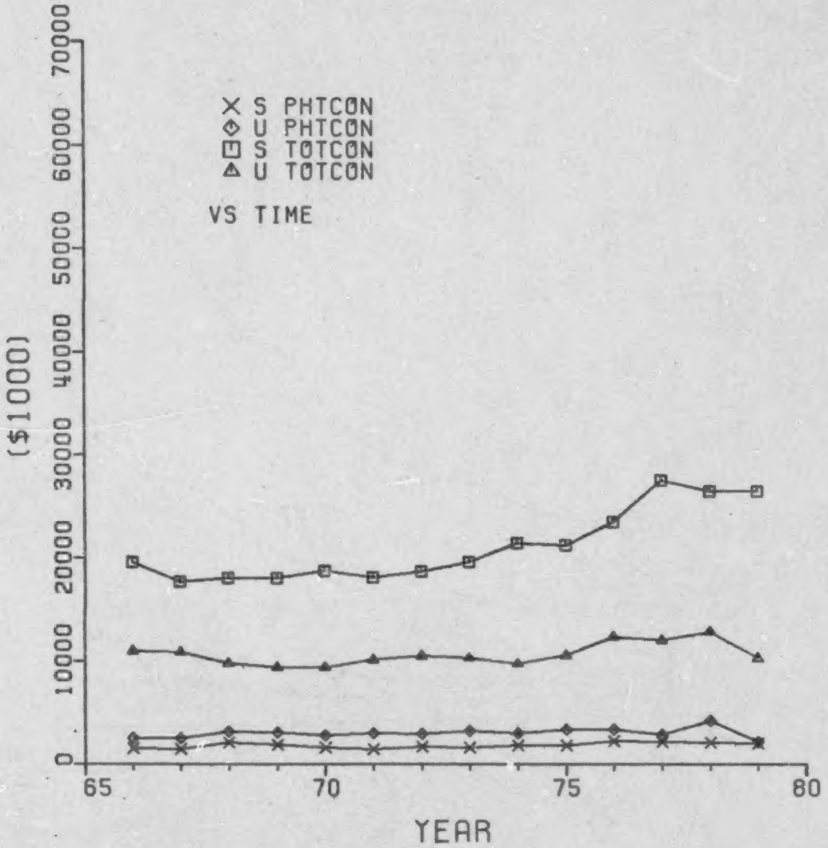
SOURCE: TABLE A-21.

FIGURE 41. BEEF PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CURRENT DOLLARS, 1966-1979.



SOURCE: TABLE A-22.

FIGURE 42. BEEF PHT AND TOTAL RESEARCH EXPENDITURES BY SAES AND USDA IN CONSTANT DOLLARS, 1966-1979.



SOURCE: TABLE A-22.

4. In general the level of expenditures and the proportion of expenditures allocated to post-harvest technology and agricultural marketing research were greater in the USDA than in the SAES.

5. In both the SAES and the USDA current dollar expenditures for PHT research exhibited an overall increase over the 1966-1979 period, but for several commodities the levels of expenditures decreased from 1977 to 1979.

6. In both the SAES and the USDA constant dollar expenditures for PHT research exhibited only slight increases or declined over the 1966-1979 period.

Agricultural Research Expenditures Relative to Scientist Years and Value of Agricultural Production

Sometimes it is a little easier to comprehend changes in variables such as agricultural research funds if they are measured relative to some base reference points. Scientist years and value of agricultural production were chosen as references to further analyze the patterns of expenditures on agricultural research. Total expenditures on agricultural research and expenditures on post-harvest technology and agricultural marketing research per scientist year and per $1000 value of agricultural production are analyzed for the SAES, USDA, and the SAES and USDA combined in both current and constant dollars for the 1966-1979 period. The latter part of this section deals with measures of research and development expenditures per scientist year by private industry which most closely resemble the per scientist year agricultural research expenditures by the SAES and USDA.

Total Agricultural Research Expenditure per Scientist Year

The per scientist year total agricultural research expenditures by the SAES, USDA, and SAES and USDA combined (total public) in current and constant dollars for the 1966-1979 period are presented in Figure 43 and Figure 44, respectively. In current dollars the total expenditures on agricultural research by the SAES, USDA, and the SAES and USDA combined steadily increased during the 1966-1979 period. The research expenditures per scientist year were higher in the USDA than in the SAES and ranged from a low of $45,265 per scientist year in 1968 to $110,460 per scientist year in 1979. In constant dollars the research expenditures per scientist year in the USDA ranged from a low of $41,419 in 1970 to a high of $46,944 in 1979. From 1966 to 1979 the constant dollar research expenditure per scientist year in the USDA increased seven percent.

In the SAES the current dollar expenditures per scientist year ranged from a low of $33,390 in 1966 to a high of $107,260 in 1979. In current dollars the overall increase from 1966 to 1979 was 171 percent but in constant dollars it was only ten percent. The constant dollar expenditures per scientist year in the SAES ranged from a low of $33,390 in 1966 to a high of $46,806 in 1978. In the SAES the 1979 constant dollar expenditure per scientist year was $45,584 or $1,360 less than the per scientist year expenditure in the USDA.

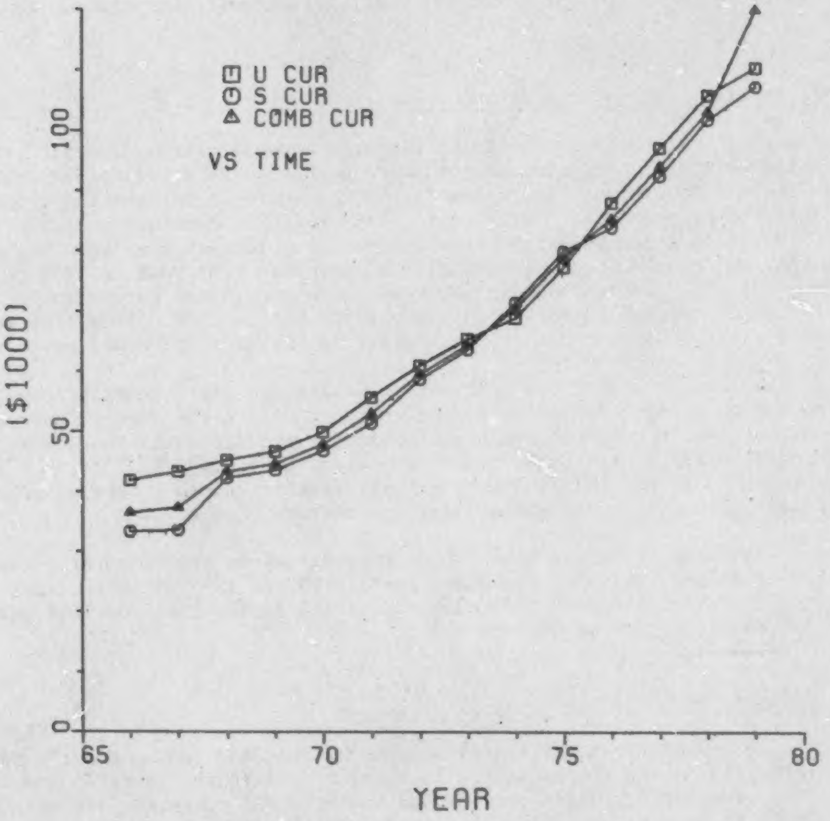
The current dollar per scientist year public expenditure on agricultural research (SAES and USDA combined) was $42,965 in 1966, increased to $127,100 in 1979. The constant dollar per scientist year expenditures of SAES and USDA combined varied during the 1966-1979 period but increased by two percent overall from 1966 to 1979.

PHT Research Expenditures per Scientist Year

The PHT research expenditures per scientist year by the SAES, USDA, and the SAES and USDA combined for the 1966-1979 period are presented in current dollars in Figure 45 and in constant dollars in Figure 46. The per scientist year expenditures on PHT research were about the same in the SAES and the USDA throughout the 1966-1979 period. In the SAES the current dollar PHT research expenditures per scientist year increased 148 percent from 1966 to 1979, but the constant dollar expenditures remained at about the same level even though within the fourteen-year period they varied from a low of just over $32,000 per scientist year to a high of slightly under $40,000 per scientist year.

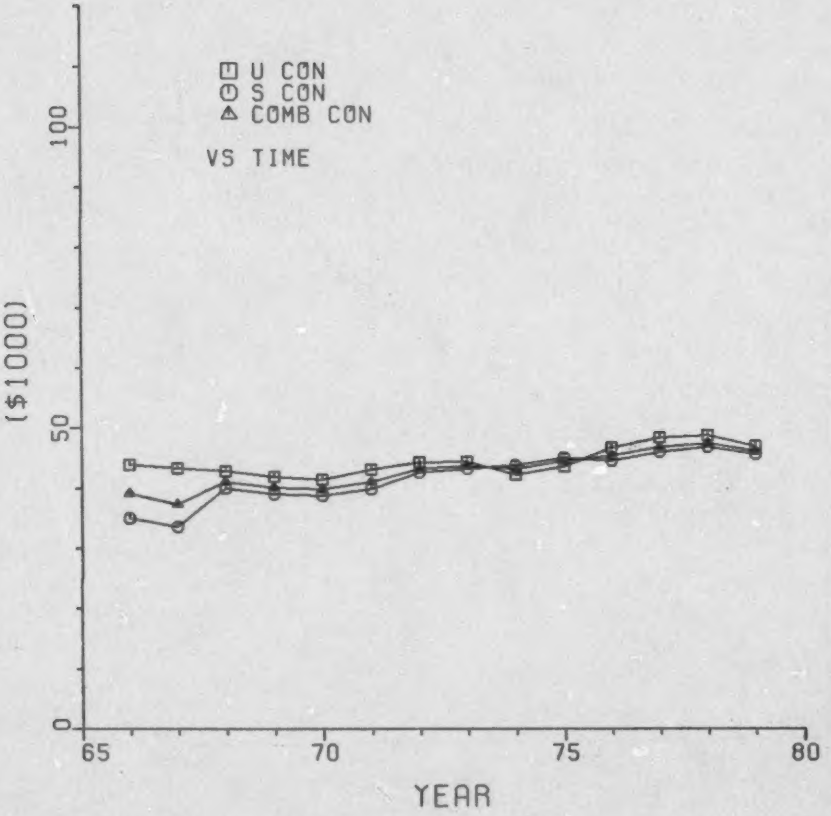
In the USDA the pattern is almost identical. In current dollars the per scientist year expenditures on PHT research increased 142 percent from 1966 to 1979. The constant dollar PHT research expenditures per scientist year decreased by two percent from 1966 to 1979, and during the fourteen-year period they varied from slightly over $36,000 per scientist year to over $38,000

FIGURE 43. PER SCIENTIST YEAR RESEARCH EXPENDITURE BY SAES, USDA, AND COMBINED SAES AND USDA IN CURRENT DOLLARS, 1966-1979.



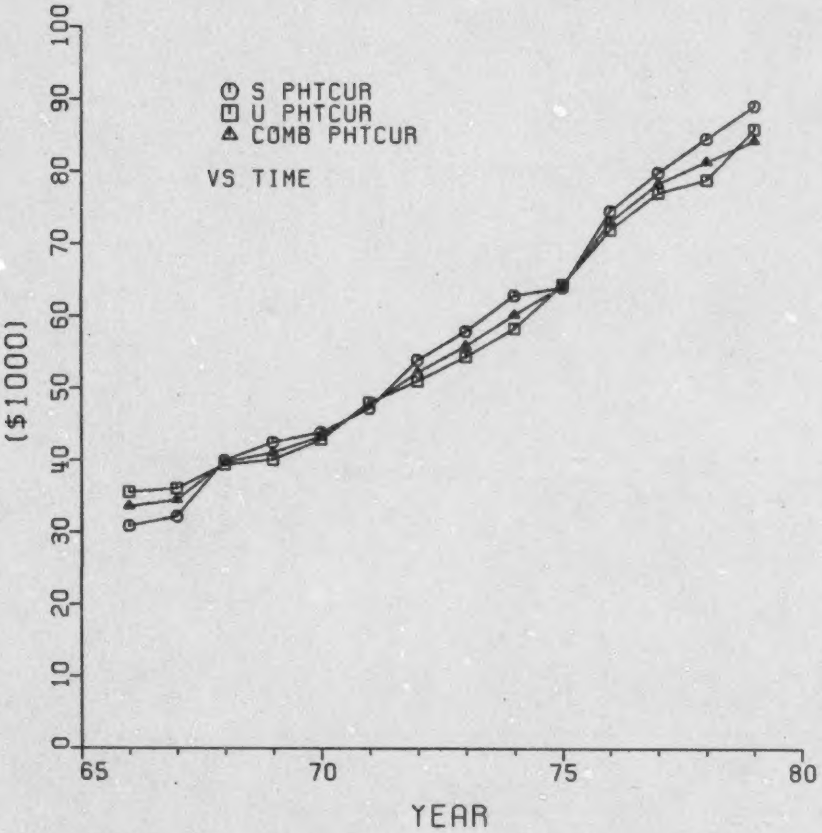
SOURCE: TABLE A-23.

FIGURE 44. PER SCIENTIST YEAR RESEARCH EXPENDITURE BY SAES, USDA, AND COMBINED SAES AND USDA IN CONSTANT DOLLARS, 1966-1979.



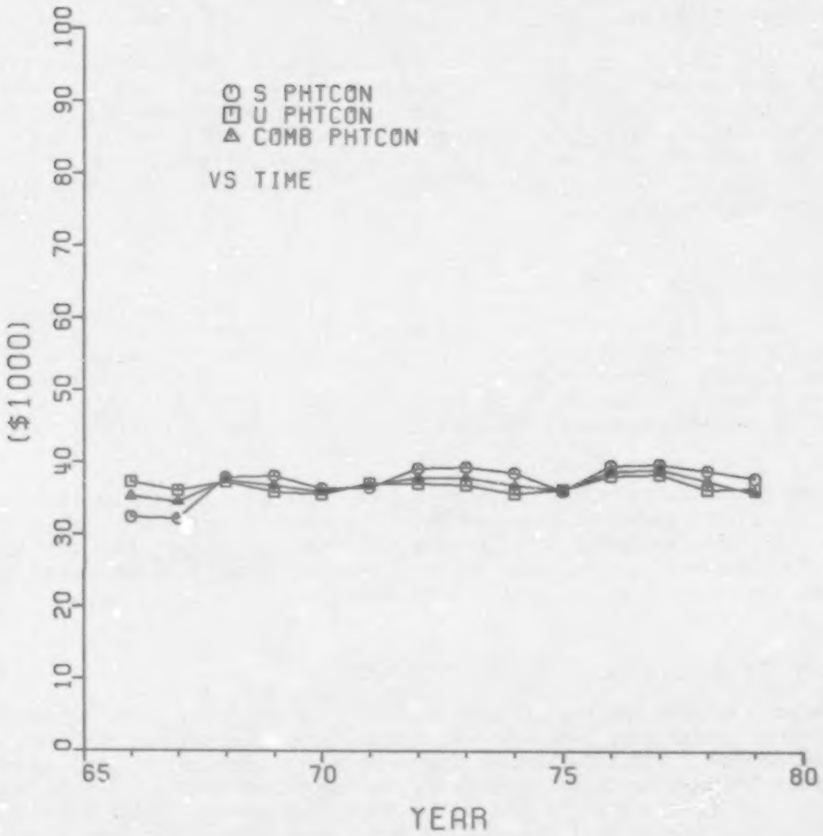
SOURCE: TABLE A-23.

FIGURE 45. PER SCIENTIST YEAR PHT RESEARCH EXPENDITURES BY SAES, USDA, AND COMBINED SAES AND USDA IN CURRENT DOLLARS, 1966-1979.



SOURCE: TABLE A-24.

FIGURE 46. PER SCIENTIST YEAR PHT RESEARCH EXPENDITURES BY SAES, USDA, AND COMBINED SAES AND USDA IN CONSTANT DOLLARS, 1966-1979.



SOURCE: TABLE A-24.

per scientist year. In other words, throughout the fourteen-year period the constant dollar expenditures on PHT research per scientist year remained at about the same level.

Total Agricultural Research Expenditures per $1000 Value of Agricultural Production

Total agricultural research expenditures per $1000 value of agricultural production for the SAES, USDA, and the combined SAES and USDA for the 1966-1979 period are presented in Figure 47. The SAES and USDA exhibit similar patterns with respect to total agricultural research expenditures per $1000 value of agricultural production. The expenditures in the SAES per $1000 value of agricultural production increased from 1966 to 1972 and then sharply declined from $4.95 per $1000 value of production in 1972 to $3.78 per $1000 value of production in 1973, reflecting the relatively high agricultural prices of that year. Thereafter the expenditures steadily increased to a high of $5.66 per $1000 value of production in 1977 and then decreased to $4.79 per $1000 of production in 1979.

In the USDA the expenditures per $1000 value of agricultural production varied from 1966 to 1979 but declined overall from $3.06 per $1000 value of agricultural output in 1966 to $2.57 per $1000 value of agricultural output in 1979.

PHT Research Expenditures per $1000 Value of Output

PHT research expenditures per $1000 value of agricultural production in the SAES, USDA, and SAES and USDA combined for the 1966-1979 period are presented in Figure 48. The expenditures on PHT research in the SAES per $1000 value of agricultural output increased from 66 cents in 1966 to a high of 85 cents in 1977 and then declined to 67 cents in 1979. In the USDA the PHT research expenditures per $1000 value of agricultural output varied throughout the 1966-1979 period, but increased from $1.08 in 1966 to a high of $1.15 in 1971 and then declined with some variation to a low of 76 cents in 1979.

SAES-USDA Relative Shares of PHT and Total Agricultural Research

Expenditures by SAES on PHT and total agricultural research as a percent of all public expenditures on PHT and total agricultural research for the 1966-1979 period are presented in Figure 49. With some minor variation the SAES proportion of total expenditures on agricultural research increased from a low of 56 percent in 1967 to a high of 65 percent in 1979. During the entire 1966-1979 period the SAES accounted for more than half of the total expenditures for public agricultural research.

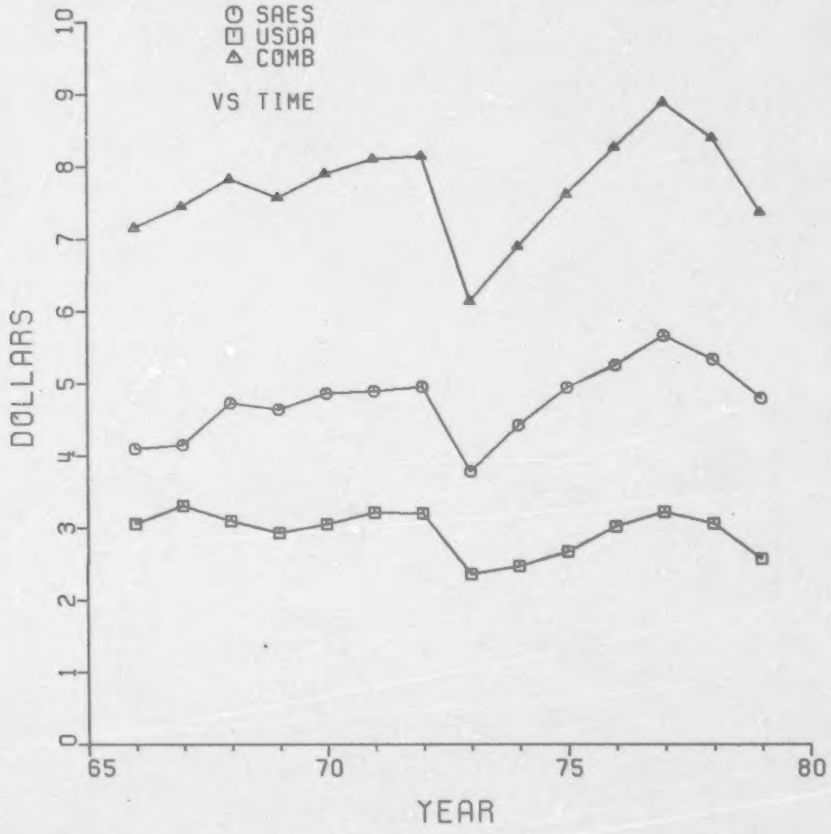
The SAES expenditures on agricultural PHT research as a percent of total expenditures on public agricultural PHT research increased about ten percent during the 1966-1979 period. Although there was slight variation, the proportion increased from about 37 percent in 1967 to 47 percent in 1979. However, during this fourteen-year period the SAES accounted for less than 50 percent of the expenditures on agricultural PHT research.

Expenditures on R and D by Selected Federal Agencies

The federal obligations for all research and development by NASA, DOE, NSF, and a category of all other (i.e., other selected) agencies for the 1966-1978 period (the most recent available data) are presented in current dollars in Figure 50 and in constant dollars in Figure 51. The level of funding for NASA is large relative to the other agencies considered. As may be observed from Figures 50 and 51, the R and D funding for NASA decreased from 1966 to 1974 and thereafter increased, although in constant dollars the increase from 1974 to 1978 was quite small. The R and D funding for DOE increased in current dollars from 1972 to 1978, but in constant dollars did not increase until after 1974. In both current and constant dollars the R and D funding for NSF increased steadily during the thirteen-year period. The R and D funding for "all other agencies" increased about 270 percent in current dollars during the 1966-1978 period, but on constant dollars increased about 67 percent.

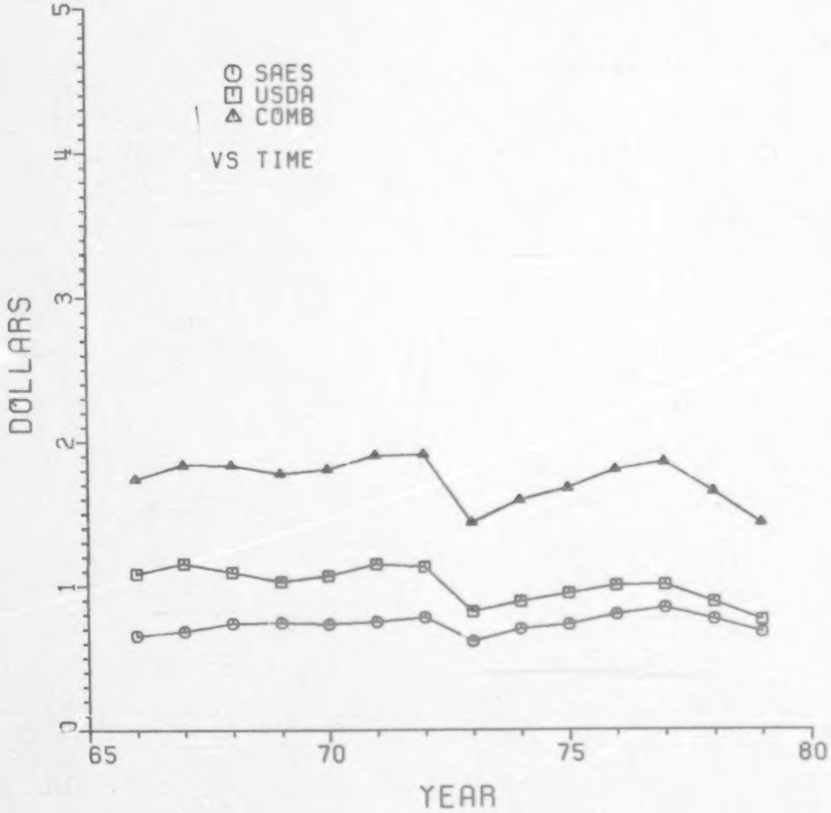
The R and D expenditures for the USDA, DOD, HEW, and the total for all federal agencies for the 1966-1978 period are presented in current dollars in Figure 52 and in constant dollars in Figure 53. In current dollars the R and D expenditures by DOD increased 68 percent from 1966 to 1978, but in constant dollars this represented a decline of 26 percent. The R and D funding for HEW increased steadily by 209 percent from 1966 to 1978 and in constant dollars the expenditures increased 35 percent. In current dollars the R and D funding for the USDA increased steadily by

FIGURE 47. TOTAL AGRICULTURAL RESEARCH EXPENDITURES PER $1000 VALUE OF AGRICULTURAL PRODUCTION BY SAES, USDA, AND COMBINED SAES AND USDA, 1966-1979.



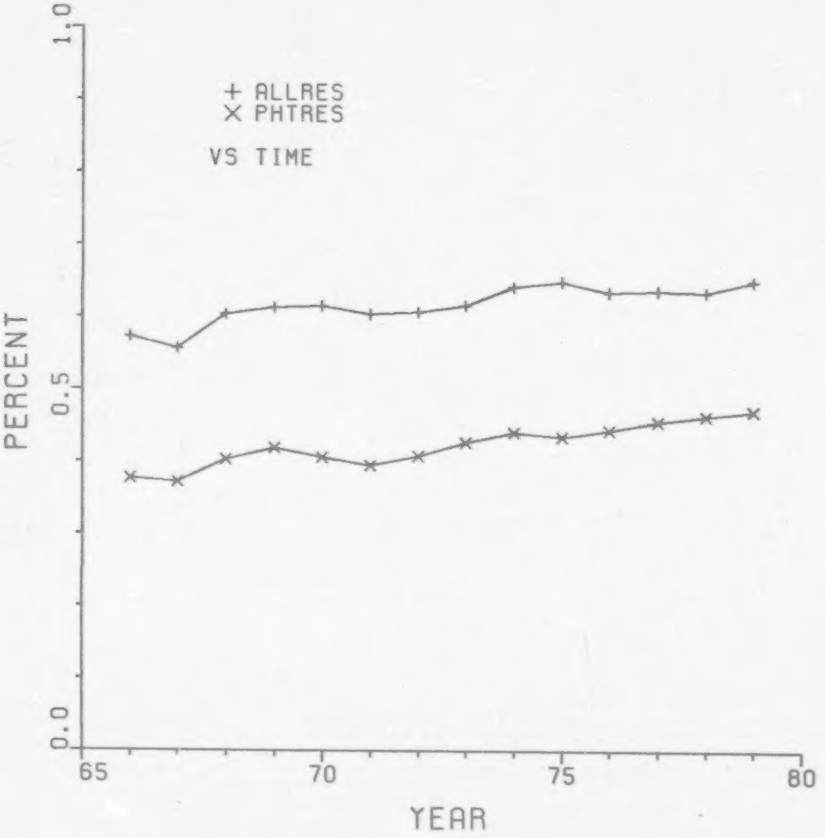
SOURCE: TABLE A-25.

FIGURE 48. PHT RESEARCH EXPENDITURES PER $1000 OF AGRICULTURAL PRODUCTION BY SAES, USDA, AND COMBINED SAES AND USDA, 1966-1979.



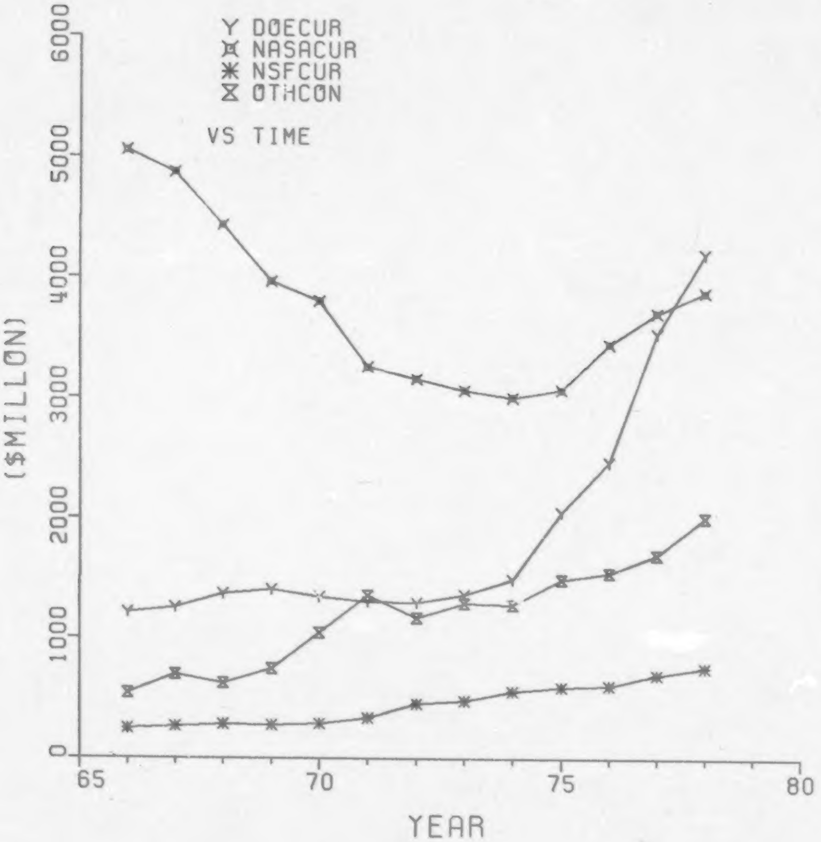
SOURCE: TABLE A-26.

FIGURE 49. SAES EXPENDITURES ON PHT AND ON ALL AGRICULTURAL RESEARCH AS A PERCENT OF COMBINED SAES AND USDA EXPENDITURES ON PHT AND ALL AGRICULTURAL RESEARCH, 1966-79.



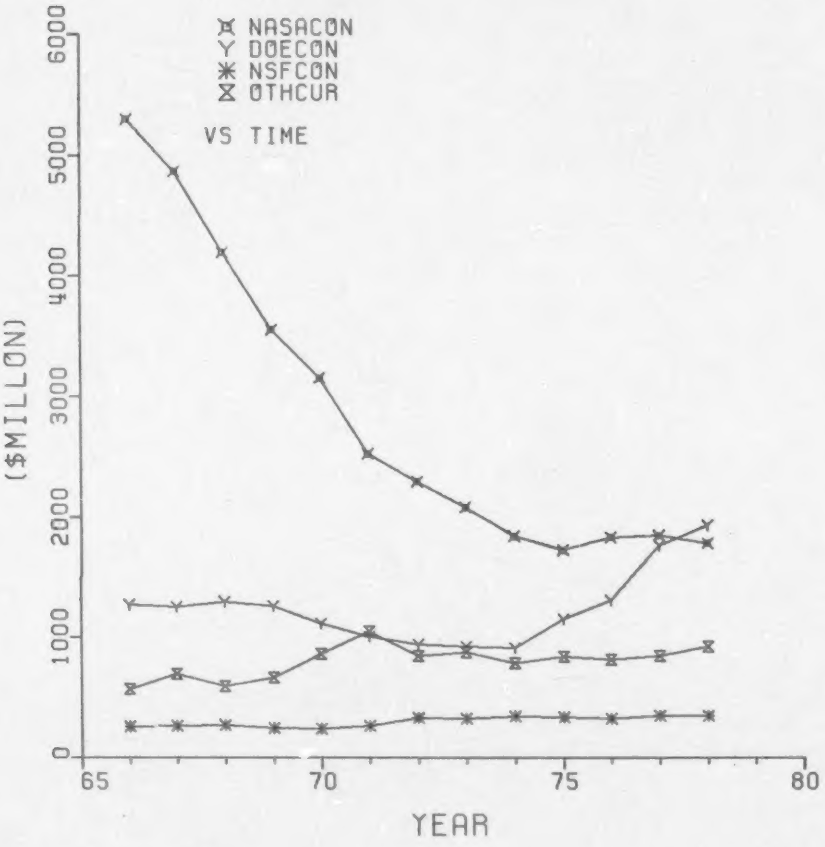
SOURCE: TABLE A-27.

FIGURE 50. FEDERAL OBLIGATIONS FOR RESEARCH AND DEVELOPMENT BY NASA, DOE, NSF, AND OTHER SELECTED AGENCIES IN CURRENT DOLLARS, 1966-1978.



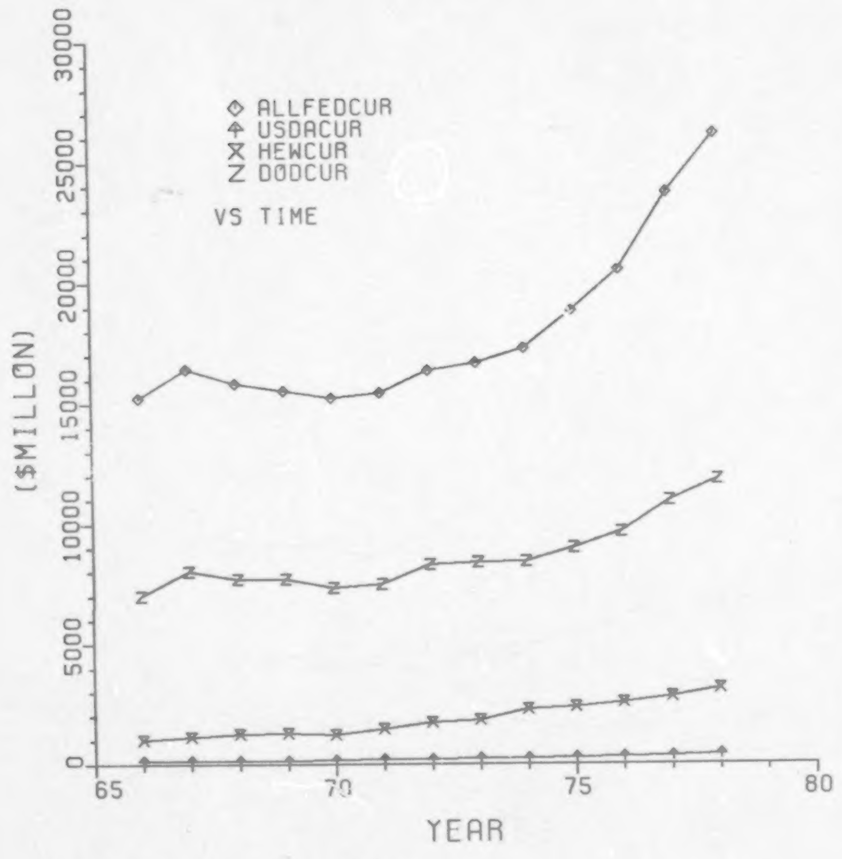
SOURCE: TABLE A-28.

FIGURE 51. FEDERAL OBLIGATIONS FOR RESEARCH DEVELOPMENT BY NASA, DOE, NSF, AND OTHER SELECTED AGENCIES IN CONSTANT DOLLARS, 1966-1978.



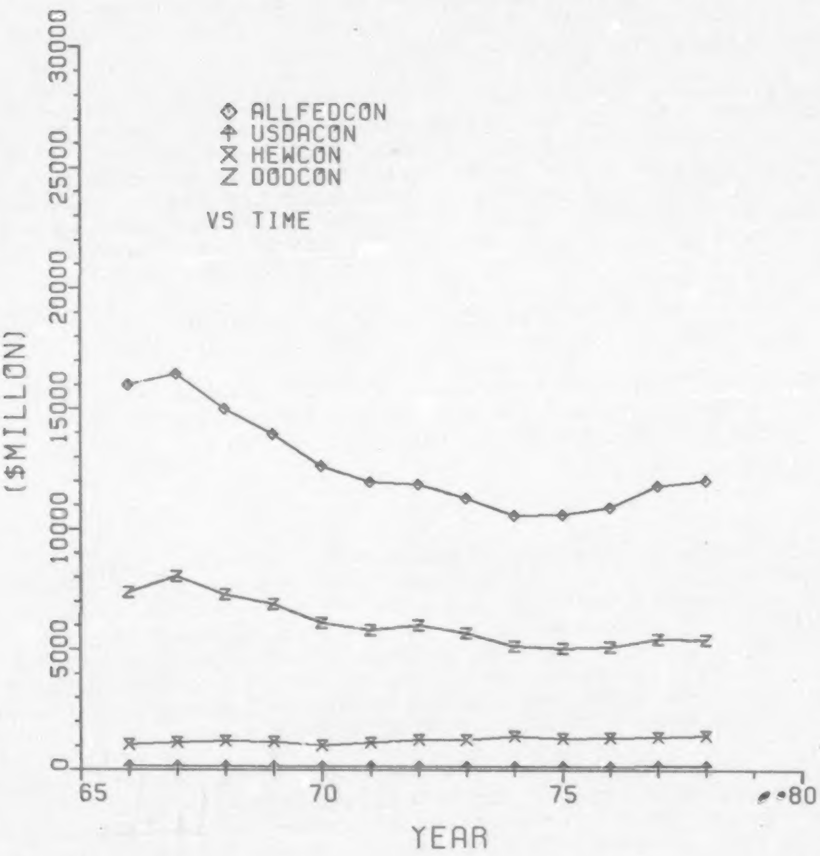
SOURCE: TABLE A-28.

FIGURE 52. FEDERAL OBLIGATIONS FOR RESEARCH AND DEVELOPMENT BY USDA, DOD, HEW, AND ALL FEDERAL AGENCIES IN CURRENT DOLLARS, 1966-1978.



SOURCE: TABLE A-28.

FIGURE 53. FEDERAL OBLIGATIONS FOR RESEARCH AND DEVELOPMENT BY USDA, DOD, HEW, AND ALL FEDERAL AGENCIES IN CONSTANT DOLLARS, 1966-1978.



SOURCE: TABLE A-28.

149 percent from 1966 to 1978 and in constant dollars by ten percent. Finally, the current dollar federal obligations for all R and D for all federal agencies increased 72 percent from 1966 to 1978, but in constant dollars this ended up being a 25 percent decrease. The pattern in the expenditures for all R and D for all federal agencies and the patterns in the R and D expenditures of NASA and DOD, the two largest agencies in terms of R and D funding, are quite similar.

Research Cost Per R and D Scientist Year in Private Industry

Data concerning the expenditures on private industry research per scientist year which are comparable to that available for the SAES and USDA are not available for private agricultural related industry. Some data are available concerning the research cost per R and D scientist or engineer year for food and kindred products, chemicals, and all private industry. These costs for the 1963-1978 period are presented in current dollars in Figure 54 and in constant dollars in Figure 55.

The patterns in Figures 54 and 55 may be summarized quite briefly. The research cost per R and D scientist or engineer year for food and kindred products, chemicals, and all private industry increased in current dollars during the 1963-1978 period. The increases from 1963 to 1978 were: food and kindred products - 137 percent; chemicals - 127 percent; and total private R and D - 110 percent. The patterns are very similar to the pattern for total agricultural research and PHT research by the SAES and USDA during the 1966-1979 period.

In constant dollars the research costs per R and D scientist or engineer year decreased during the 1963-1978 period for food and kindred products, chemicals, and all private industry. The decrease in research costs per scientist or engineer was six percent in food and kindred products, ten percent in chemicals, and seventeen percent in all private industries. The R and D expenditures per scientist or engineer year in the chemical and all private industries were similar to the expenditures on PHT research per scientist year in the SAES and USDA, but the per scientist or engineer year expenditures in the food and kindred industries were lower.

Expenditures on PHT, Production, Other, and Total Agricultural Research by Services of the USDA

In this section the patterns in expenditures on PHT, production, other, and total agricultural research for the major services within the USDA are analyzed for the 1966-1979 period. The services considered were ARS, ESS, and CR.

ARS

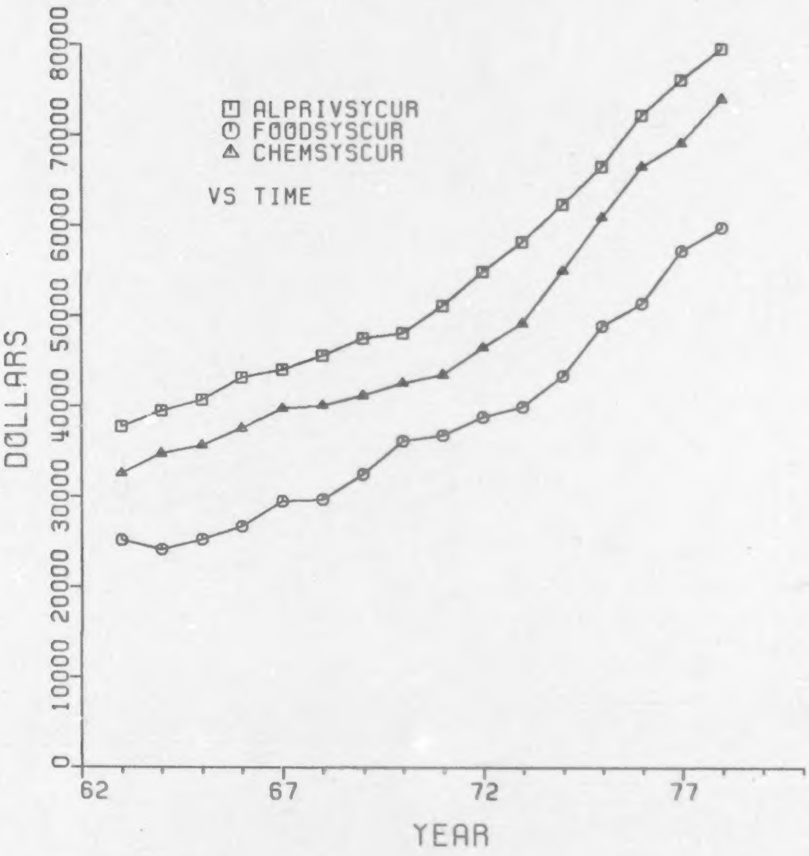
Current dollar expenditures on PHT, production, other, and total agricultural research by ARS for the 1966-1979 period are presented in Figure 56 and constant dollar expenditures are presented in Figure 57. In terms of research funding the ARS was by far the largest service in the USDA during 1966-1979. Total current dollar expenditures on agricultural research increased 139 percent during the 1966-1979 period. In 1966 the total expenditures on agricultural research were about $137 million, and these expenditures increased to approximately $327 million in 1979. With considerable year to year fluctuation, the constant dollar total expenditures on agricultural research decreased from $144 million in 1966 to $139 million in 1979.

Production research constituted the largest part of total agricultural research funding in ARS. Expenditures on production research exhibit a pattern similar to that of total research expenditures. Current dollar expenditures on production research increased fairly streadily throughout the 1966-1979 period. In current dollars the expenditures on production research were about $85 million in 1966 and increased by 162 percent to $223 million in 1979. Constant dollar expenditures on production research fluctuated during the fourteen-year period, but overall the constant dollar expenditure increased by six percent from about $90 million in 1966 to $95 million in 1979.

After a slight decrease from 1967 to 1968, the current dollar expenditures on PHT research steadily increased from about $46 million in both 1966 and 1968 to $86 million in 1979. In constant dollars the expenditures on PHT research exhibited some variation during the fourteen-year period, but decreased by 24 percent overall from 1966 to 1979.

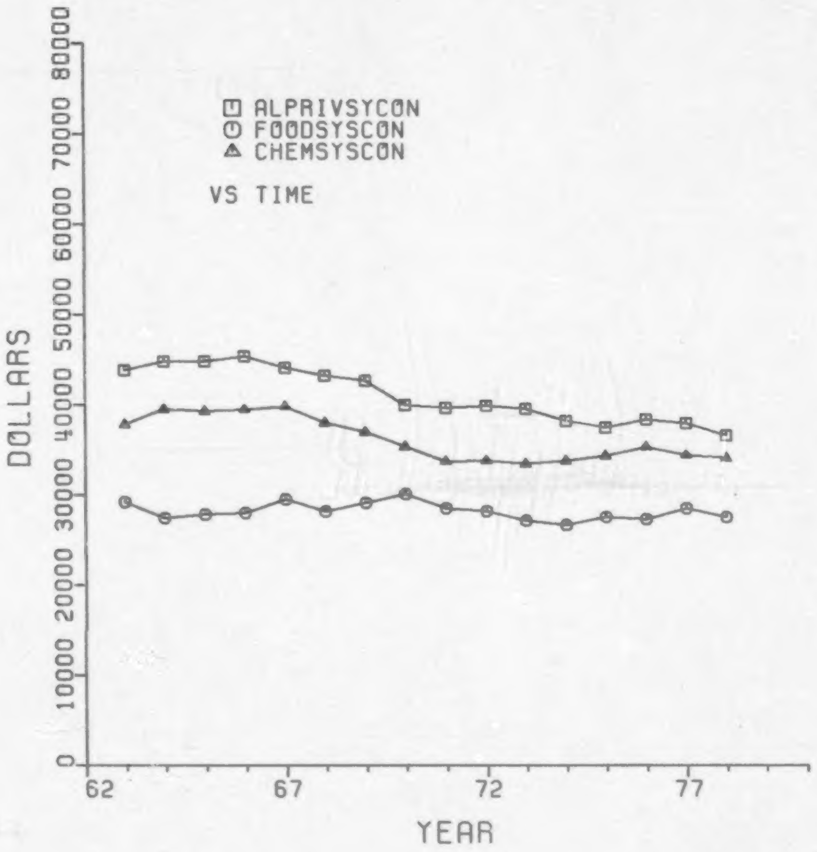
The remaining component of ARS agricultural research is the category labelled other. This was a small component and the expenditures in both current and constant dollars steadily increased from 1966 to 1978, but decreased by nearly $10 million from 1978 to 1979. In current dollars the

FIGURE 54. RESEARCH COST PER R+D SCIENTIST YEAR FOR FOOD AND KINDRED PRODUCTS, CHEMICALS, AND FOR ALL PRIVATE INDUSTRY IN CURRENT DOLLARS, 1963-1978.



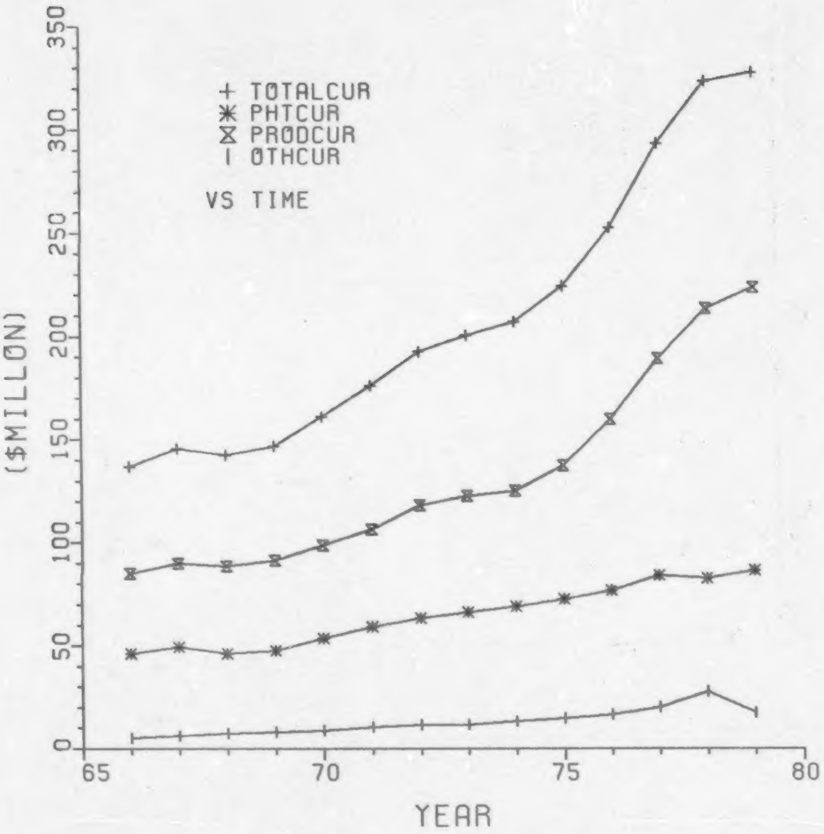
SOURCE: TABLE A-29.

FIGURE 55. RESEARCH COST PER R+D SCIENTIST FOR FOOD AND KINDRED PRODUCTS, CHEMICALS, AND FOR ALL PRIVATE INDUSTRY IN CONSTANT DOLLARS, 1963-1978.



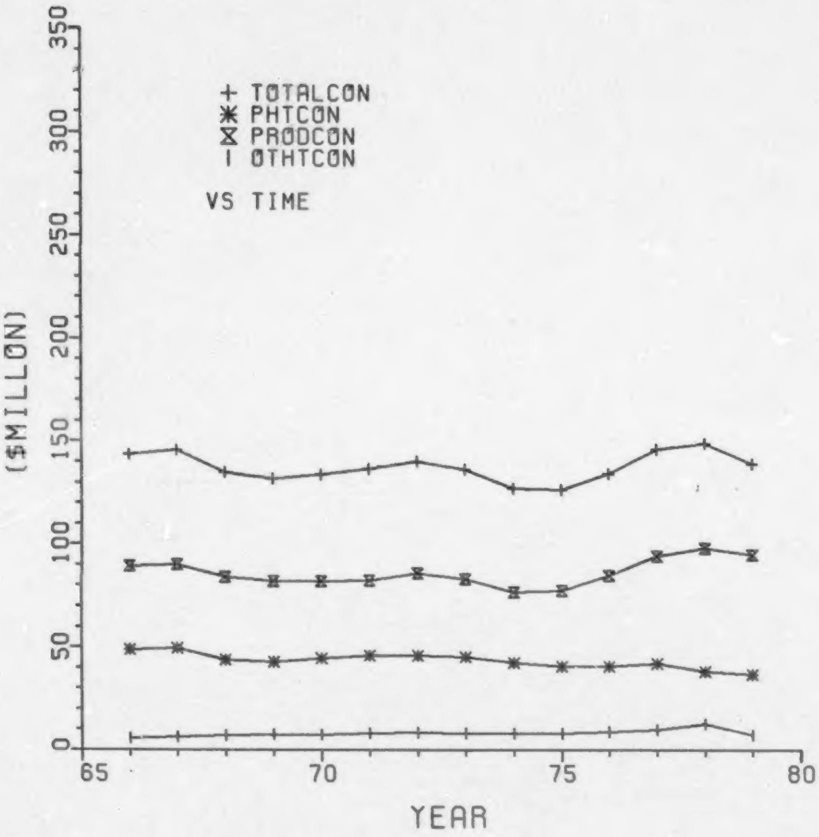
SOURCE: TABLE A-29.

FIGURE 56. HRS PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH EXPENDITURES IN CURRENT DOLLARS, 1966-1979.



SOURCE: TABLE A-30.

FIGURE 57. ARS PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH EXPENDITURES IN CONSTANT DOLLARS, 1966-1979.



SOURCE: TABLE A-30.

expenditure was a little over $5 million in 1966 and increased to nearly $28 million in 1978. In constant dollars the expenditures on other research in ARS increased from nearly $6 million in 1966 to over $13 million in 1978, but declined to about $7.5 million in 1979.

ESS

Current dollar expenditures on PHT, production, other, and total agricultural research in ESS for the 1966-1979 period are presented in Figure 58, and constant dollar expenditures are presented in Figure 59. In current dollars total research expenditures in ESS increased by 128 persent from 1966 to 1979 but constant dollar expenditures decreased by eight percent.

Expenditures on PHT research were the largest component of total research expenditures in ESS. Remember that agricultural marketing research is considered a part of PHT research and ESS is heavily engaged in agricultural marketing research. Expenditures on PHT research in current and constant dollars exhibit patterns similar to total agricultural research expenditures in ESS. In both current and constant dollars the PHT research expenditures increased from 1966 to 1979. The increase in current dollar expenditures was 177 percent and the increase in constant dollar expenditures was twelve percent.

Expenditures in ESS on other research varied substantially and show some erratic patterns in both current and constant dollars. The overall increase from 1966 to 1979 in current dollar expenditures on other research was 116 percent, while constant dollar expenditures decreased thirteen percent. Throughout the fourteen-year period the expenditures on other research accounted for about a third of the total research expenditures of ESS.

Expenditures on production research were the smallest component of total agricultural research expenditures in ESS. Expenditures on production research accounted for about sixteen percent of total research expenditures in ESS during the early part of the 1966-1979 period and declined to a low of two percent in 1971. Thereafter, the proportion varied and reached fourteen percent in 1978 but declined to seven percent in 1979. In current dollars the expenditures on production research in the ESS increased only three percent from 1966 to 1979 and constant dollar expenditures declined 58 percent. The small proportion which production research expenditures were of total research expenditures and the large decline in constant dollar expenditures on production research were unique to ESS relative to other agencies of the USDA.

CR

Current dollar expenditures by CR on PHT, production, other, and total agricultural research for the 1966-1979 period are presented in Figure 60 and constant dollar expenditures are presented in Figure 61. These expenditures refer to funds used within the USDA for administering research funds in the states and to obligations of CR administered special grants.

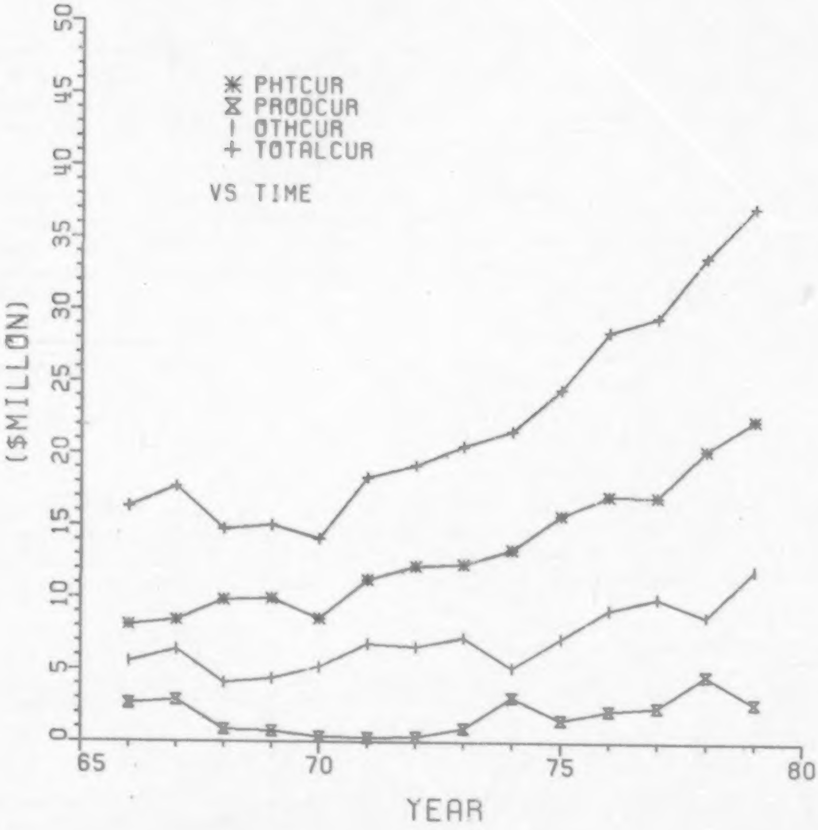
Prior to 1967 expenditures were not reported for CR or its predecessor CSRS. Furthermore, until 1971 the total research expenditures by CR were under $2 million per year, most of which were devoted to production research. In current dollars the total expenditures increased from 1967 to a peak of $23.7 million in 1978 and then declined to $16.9 million in 1979. The overall increase in total research expenditures in CR from 1967 to 1979 was 748 percent, and the constant dollar expenditures for the same period increased 260 percent.

Expenditures on production research constituted a large part of the total research expenditures of CR and exhibit patterns similar to total expenditures on agricultural research. In 1967 the entire research expenditures of CR consisted of expenditures on production research. Current dollar expenditures on CR on production research increased 468 percent from 1967 to 1979 and the corresponding constant dollar expenditures increased 141 percent. From 1975 to 1979 expenditures on production research as a percent of total research expenditures in CR ranged from 41 percent in 1975 to 67 percent in 1979.

Until 1972 the expenditures on PHT research were nearly nil, and after 1972 the current dollar expenditures increased to about $6.9 million in 1978 and then decreased to $3.5 million in 1979. In 1979 the current dollar expenditures were slightly below the 1972-1973 level. In constant dollars the expenditures by CR on PHT research decreased by 43 percent from 1972 to 1979.

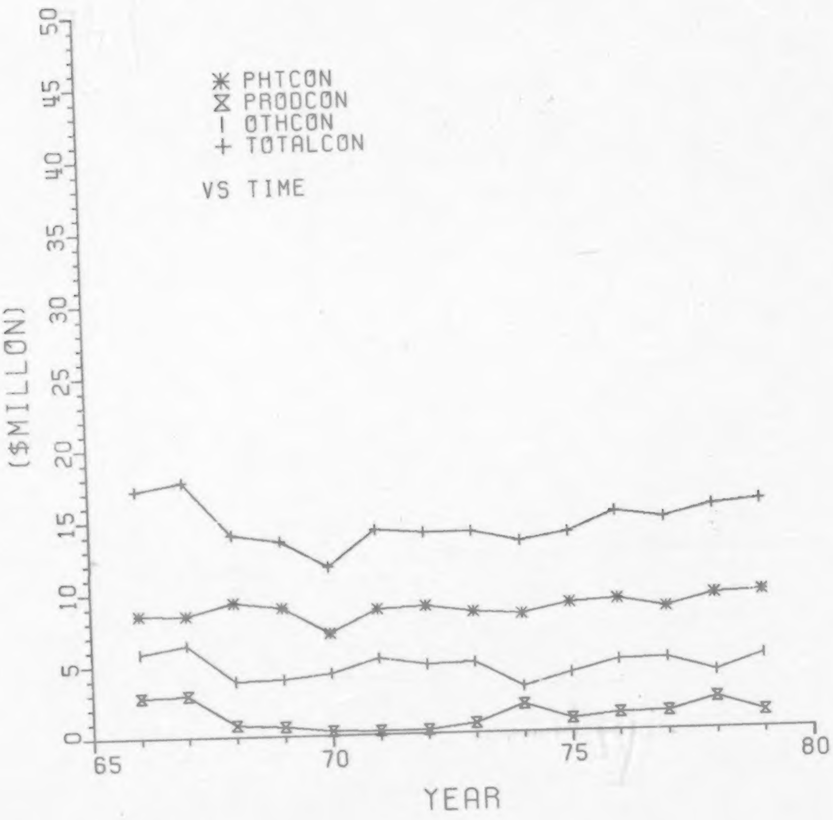
The expenditures on other research were also nearly nil until 1972 but increased from about $2.9 million in 1972 to $5.1 million in 1977, then declined to about $2.0 million in 1979. In current dollars the expenditures declined by 31 percent from 1972 to 1979 and in constant dollars expenditures declined by 59 percent.

FIGURE 58. ESS PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH EXPENDITURES IN CURRENT DOLLARS, 1966-1979.



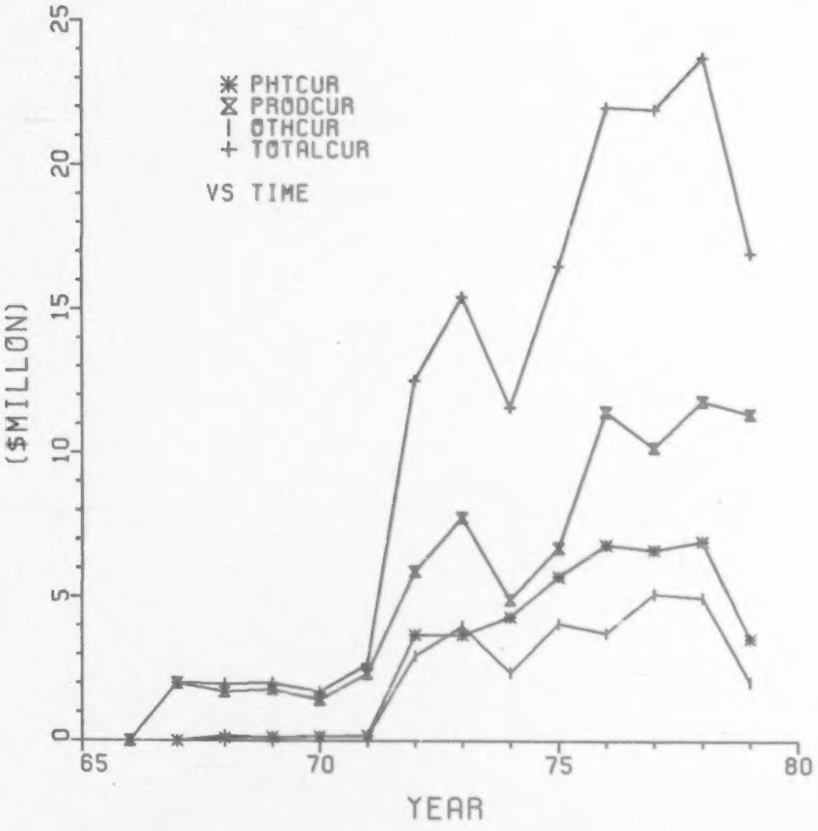
SOURCE: TABLE A-31.

FIGURE 59. ESS PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH EXPENDITURES IN CONSTANT DOLLARS, 1966-1979.



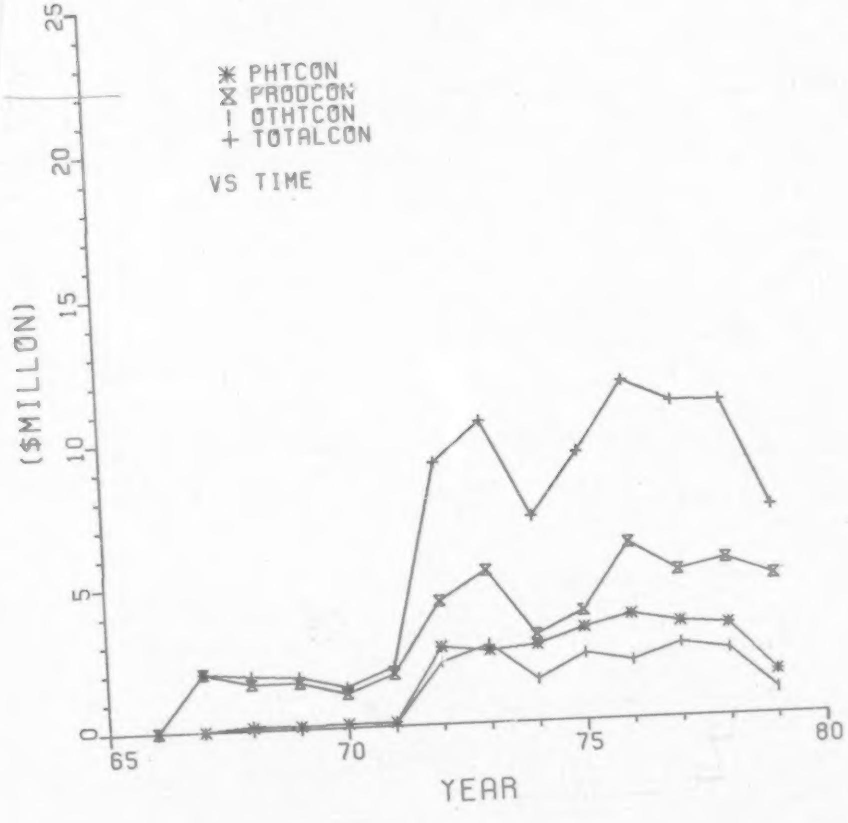
SOURCE: TABLE A-31.

FIGURE 60. CR PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH EXPENDITURES IN CURRENT DOLLARS, 1966-1979.



SOURCE: TABLE A-32.

FIGURE 61. CR PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH EXPENDITURES IN CONSTANT DOLLARS, 1966-1979.



SOURCE: TABLE A-32.

Federal Funds for R and D in Private Industry

Data concerned with federal funding of research and development in private industry are limited. National Science Foundation Report 77-324 contains some data pertaining to federal funds for R and D by industry for the 1964-1975 period. Federal funds for R and D in the food and kindred products industry in current and constant dollars for the 1964-1975 period are presented in Figure 62.

The federal funding of R and D in the food and kindred products industry was very modest during the 1964-1975 period. It ranged from $1 million to $3 million in current dollars and from $0.6 million to $3.2 million in constant dollars. In both current and constant dollars the funds varied between these respective extremes with no particular pattern over time.

PHT, Production, Other, and Total Agricultural Research Expenditures by SAES by Source of Funds

Trends in expenditures on PHT, production, other, and total agricultural research by types of funds at SAES are analyzed in this section. The types or sources of funding considered were federal formula funds, cooperative grants and agreements, other federal sources, regional research funds, state appropriations, and private research funds to SAES.

Federal Formula Funds to the States

Current dollar expenditures on PHT, production, other, and total agricultural research at SAES and 1890 Institutions from federal formula funds for the 1966-1979 period are presented in Figure 63 and constant dollar expenditures are presented in Figure 64. The total expenditures on agricultural research from federal formula funds steadily increased in current dollars from about $48 million in 1966 to nearly $143 million in 1979, which is an increase of 197 percent. These expenditures do not include funds for research on forestry and forest products, human nutrition, environment, and some other non-agricultural problem areas. Constant dollar expenditures on agricultural research from formula funds varied during the fourteen-year period but increased about 20 percent overall.

A large proportion of the federal formula funds (65 percent in 1966 and 70 percent in 1979) were allocated to production research. The current dollar expenditures on production research increased 218 percent from 1966 to 1979 and exhibit a pattern similar to that of total agricultural research expenditures. The constant dollar expenditures on production research varied between $28 million and $42 million during the fourteen-year period and increased 29 percent from 1966 to 1979.

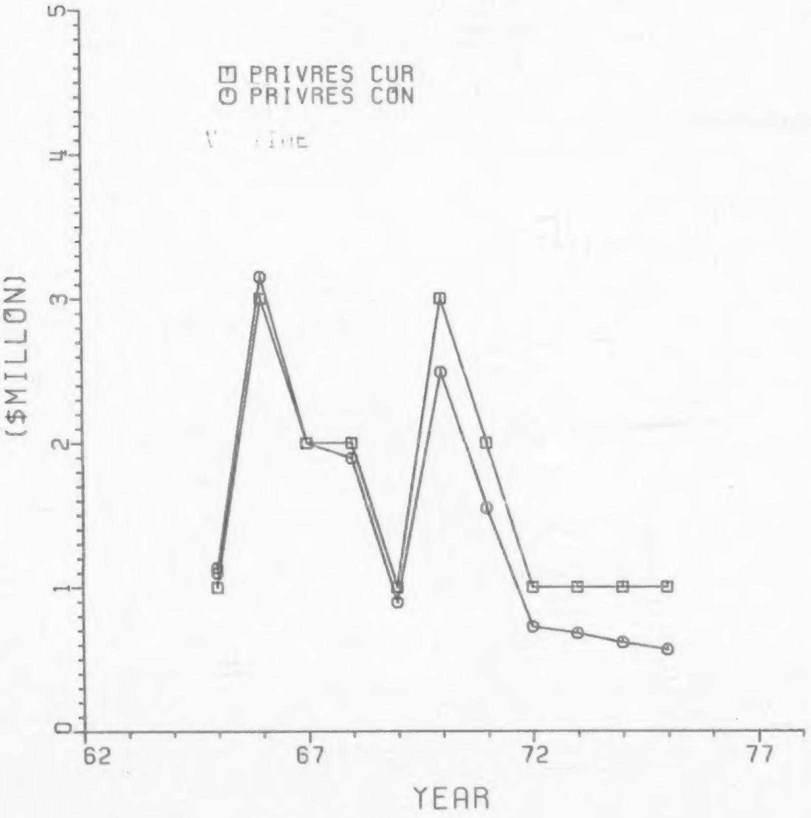
Current dollar expenditures on PHT research from federal formula funds increased steadily from a little under $11 million in 1966 to slightly over $28 million in 1977 but thereafter decreased to $23 million in 1979. The overall increase in current dollar expenditures from 1966 to 1979 was 110 percent. However, constant dollar expenditures decreased by fifteen percent from 1966 to 1979, and they exhibit an especially pronounced decline from 1977 to 1979. Expenditures on PHT research from federal formula funds were 23 percent of total formula funds in 1966 and only sixteen percent in 1979.

Current dollar expenditures from federal formula funds on other agricultural research steadily increased from 1966 to 1977 and then declined slightly from 1977 to 1979. The overall increase from 1966 to 1979 in current dollar expenditures on other agricultural research was 249 percent. The corresponding increase in constant dollar expenditures was 41 percent. Other agricultural research was a relatively small part of total expenditures on agricultural research from federal formula funds and ranged from twelve percent in 1966 to eighteen percent in 1977 and then declined to fourteen percent in 1979.

Cooperative Grants and Agreements to States

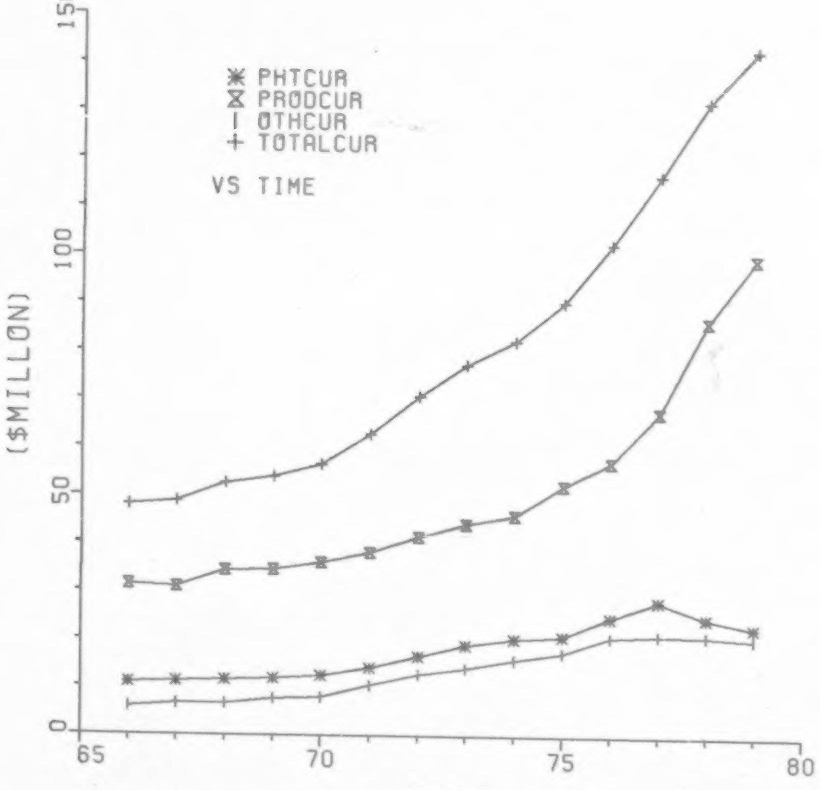
Another federal source of funding to the states is cooperative grants and agreements. The current dollar expenditures on PHT, production, and other agricultural research from cooperative grants and agreements for the 1966-1979 period are presented in Figure 65 and constant dollar expenditures are presented in Figure 66. With some variation total current dollar expenditures from cooperative grants and agreements increased 197 percent from 1966 to 1979. The corresponding constant dollar expenditures increased twenty percent.

FIGURE 62. FEDERAL FUNDS FOR AGRICULTURAL RESEARCH BY PRIVATE INDUSTRY, CURRENT AND CONSTANT DOLLARS, 1963-1975.



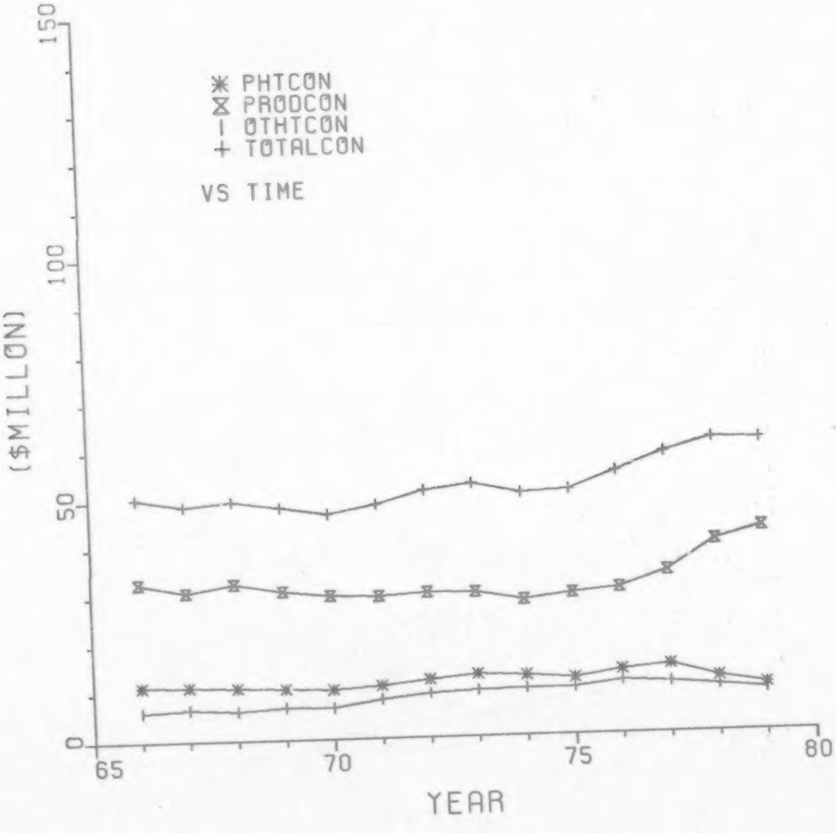
SOURCE: TABLE A-33.

FIGURE 63. SAES FEDERAL FORMULA EXPENDITURES FOR TOTAL, PHT, PRODUCTION, AND OTHER RESEARCH IN CURRENT DOLLARS, 1966-1979.



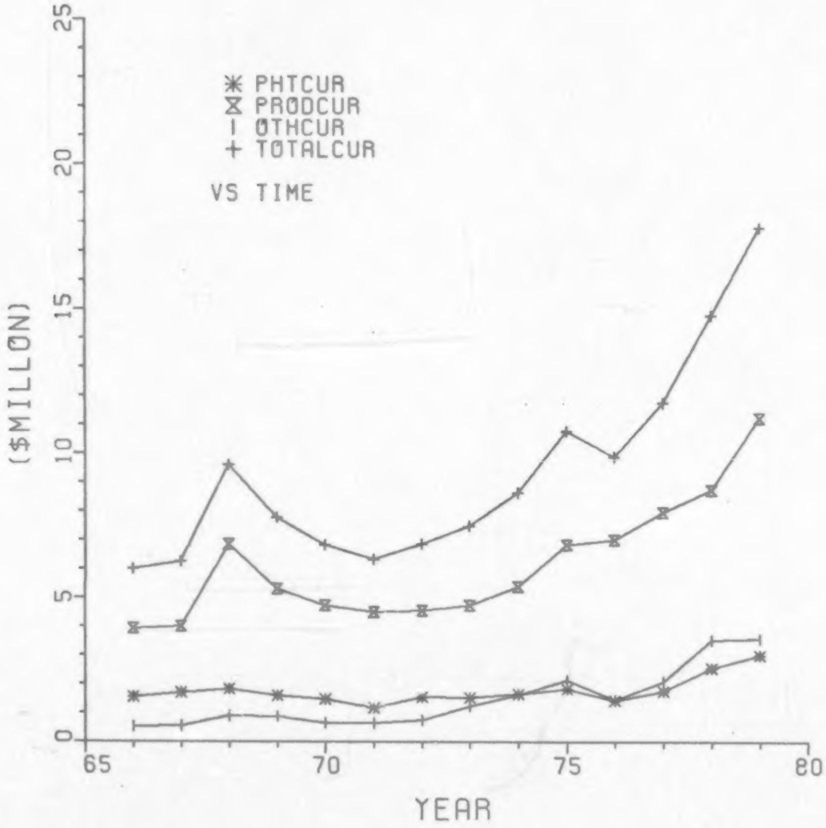
SOURCE: TABLE A-34.

FIGURE 64. SAES FEDERAL FORMULA PHT EXPENDITURE FOR TOTAL, PHT, PRODUCTION, AND OTHER RESEARCH IN CONSTANT DOLLARS, 1966-1979.



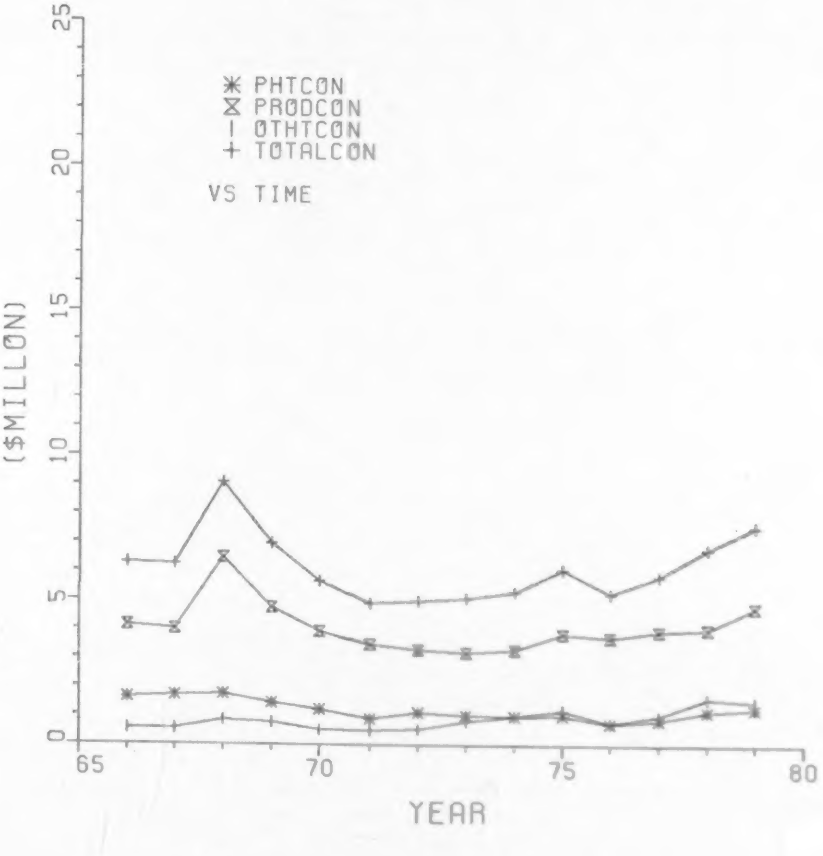
SOURCE: TABLE A-34.

FIGURE 65. SAES COOPERATIVE GRANTS AND COOPERATIVE AGREEMENTS (CGCA) EXPENDITURES FOR TOTAL, PHT, PRODUCTION, AND OTHER RESEARCH IN CURRENT DOLLARS, 1966-1979.



SOURCE: TABLE A-35.

FIGURE 66. SAES COOPERATIVE GRANTS AND COOPERATIVE AGREEMENTS (CGCA) EXPENDITURES FOR TOTAL, PHT, PRODUCTION, AND OTHER RESEARCH IN CONSTANT DOLLARS, 1966-1979.



SOURCE: TABLE A-35.

Expenditures on production research were the largest component of the research funds from cooperative grants and agreements. In 1966 they comprised 65 percent of the total research funds and in 1979 they were 63 percent. The patterns in expenditures on production research in current and constant dollars are similar to those for total expenditures on agricultural research. In current dollars the expenditures increased 186 percent from 1966 to 1979. In constant dollars the corresponding increase was only sixteen percent.

Current dollar expenditures on PHT research from cooperative grants and agreements varied during the 1966-1979 period but increased by 93 percent overall from 1966 to 1979. In constant dollars expenditures from cooperative grants and agreements on PHT research decreased 22 percent from 1966 to 1979. Expenditures on PHT research as a percent of total expenditures on agricultural research from cooperative grants and agreements decreased from 26 percent in 1966 to seventeen percent in 1979.

Current dollar expenditures from cooperative grants and agreements on other agricultural research increased from about one-half million dollars in 1966 to $3.6 million in 1979 for an increase of 575 percent. In constant dollars the corresponding increase was 177 percent. However, other research expenditures have been a small component of total agricultural research expenditures from cooperative grants and agreements and increased from about nine percent in 1966 to twenty percent in 1979.

Other Federal

The other federal category includes obligations of funds reserved by SAES from contracts, grants, and cooperative agreements with federal agencies other than the USDA. Expenditures on PHT, production, and other agricultural research from other federal sources in current and constant dollars for the 1966-1979 percent are presented in Figures 67 and 68, respectively. Total expenditures in current dollars exhibited some variation but increased by 129 percent overall from 1966 to 1979. However, in constant dollars the total expenditures decreased by seven percent from 1966 to 1979.

Expenditures on production research were the largest component of other federal funds during the 1966-1979 period and with some minor deviations exhibit patterns in both current and constant dollars which are similar to those exhibited by total expenditures. During the fourteen-year period expenditures on production research were about two-thirds of the expenditures from other federal funds. In current dollars expenditures on production research increased by 116 percent from 1966 to 1979. In constant dollars the expenditures on production research declined by sixteen percent.

Current dollar expenditures from other federal sources on PHT research show some minor variation during the 1966-1979 period, but overall the expenditures increased by 151 percent from 1966 to 1979. The corresponding increase in constant dollar expenditures was only two percent and that occurred because of the increase in expenditures from 1976 to 1979.

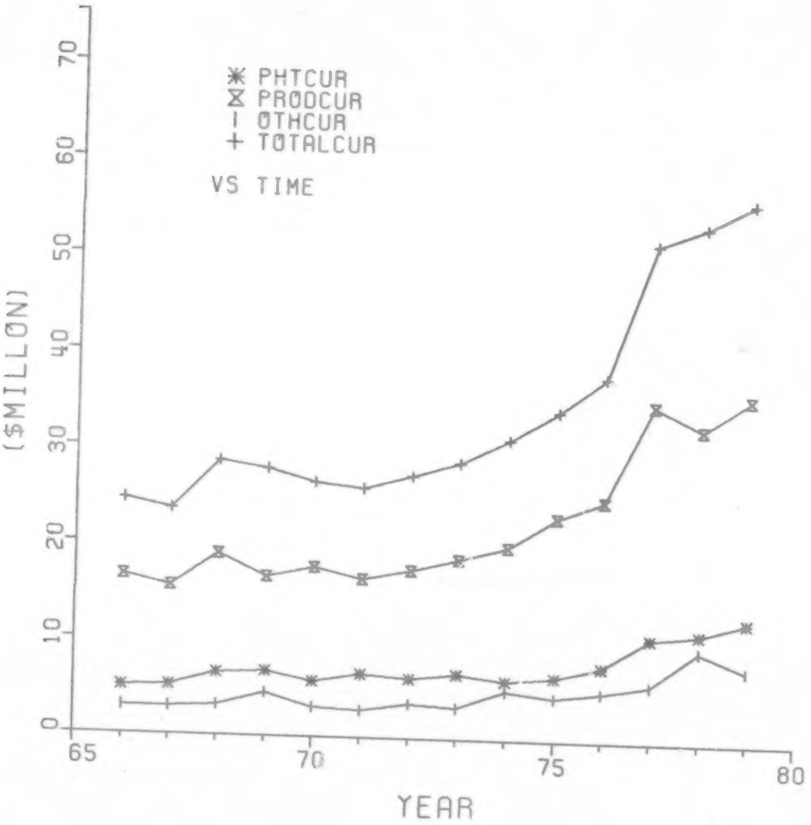
Current and constant dollar expenditures on other research fluctuated throughout the 1966-1979 period and both peaked in 1978. In current dollars the overall increase from 1966 to 1979 was 165 percent and in constant dollars the increase was only seven percent. Expenditures on other agricultural research as a percent of total expenditures on agricultural research from other federal sources was about twelve percent during the late 60's and early to mid 70's, but increased to a high of eighteen percent in 1978, and then declined to slightly under fourteen percent in 1979.

Regional Research

Research funds for regional research have been used by the states for (1) research on regional problems and (2) regional research on problems. The original intent and traditional view of regional research was for researchers from two or more states in a region to work on a problem of the region or alternatively to work on a problem common to two or more states in the region, but not necessarily occurring in all states of the region. Thus, research on regional problems deals either with problems which cannot be solved by a particular state or with problems which might be solved by a state, but which could be more effectively solved by the cooperation of two or more states within a region.

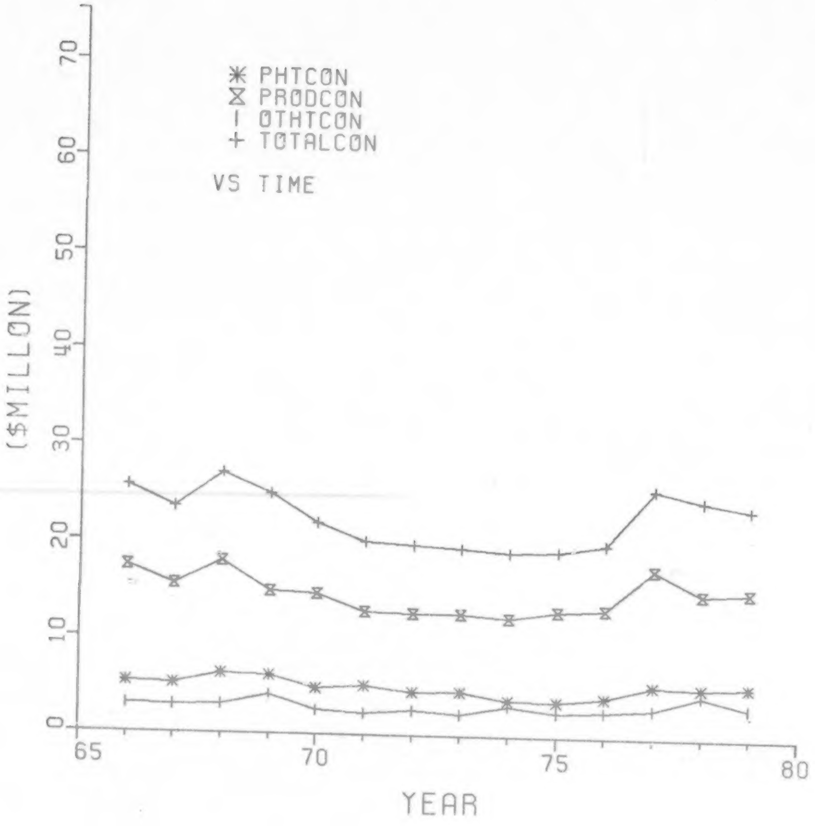
Regional research on problem entails scientists from two or more states coordinating research on problems which affect more than one region. The particular problems may impact on several states not located in the same geographical region of the U.S. (production, demand, and consumption issues pertaining to specific commodities, e.g., citrus, or to public programs such as

FIGURE 67. SAES OTHER FEDERAL EXPENDITURES FOR TOTAL, PHT, PRODUCTION, AND OTHER RESEARCH IN CURRENT DOLLARS, 1966-1979.



SOURCE: TABLE A-36.

FIGURE 68. SAES OTHER FEDERAL EXPENDITURES FOR TOTAL, PHT, PRODUCTION, AND OTHER RESEARCH IN CONSTANT DOLLARS, 1966-1979.



SOURCE: TABLE A-36.

food stamps), may be national in scope (e.g., agricultural policy issues), or may be international in scope (production and marketing problems involving export commodities). This type of regional research coordinates the research efforts of scientists with complementary expertise on a problem that is not individual state specific nor even geographic region specific, but one of national importance or possibly having some international, particularly trade, dimensions.

Priorities on regional research problems are generally established by scientists through their SAES directors or by the SAES directors themselves. In some cases the scientists or SAES directors directly identify the problem and recognize its regional or national dimensions. In other cases the problem emerges as a severe outbreak of a disease or some other type of epidemic. Frequently the problem is called to the attention of the scientists or SAES directors by extension personnel, or directly by producers and industry personnel. The urgency of the problem determines how quickly scientists with appropriate expertise are brought together to consider the problem. In emergency cases communication among scientists has occurred within a few hours and the scientists may be meeting on the problem within a few days.

Generally regional research in which states engage is not totally funded from regional research funds. Usually state funds from other sources supplement the regional research funds. The state funds from other sources often support all or part of salaries, travel, overhead costs of the scientists, and in some cases provide direct support for conducting the research. Data are not available on expenditures on regional research other than the Hatch funds designated for regional research.

The current dollar expenditures on regional agricultural research funded under regional research during the 1966-1979 period are presented in Figure 69 and the corresponding dollar expenditures are presented in Figure 70. Current and constant dollar regional research expenditures for the 1966-1979 period are presented in Figures 71 and 72, respectively, for the Northeastern Region; in Figures 73 and 74, respectively, for the Southern Region; in Figures 75 and 76, respectively, for the North Central Region; and in Figures 77 and 78, respectively, for the Western Region.

In current dollars the total expenditures on research funded under regional research in the U.S. decreased from $9.7 million in 1966 to about $9 million in 1967, steadily increased to $24.4 million until 1978, and then declined to $23.3 million in 1979. Over the entire fourteen-year period the increase in current dollar expenditures varied quite a bit during the period and increased by one percent from 1966 to 1978 but then declined by twelve percent from 1978 to 1979. From 1966 to 1979 constant dollar expenditures on regional research exhibited an overall decline of three percent.

Production research was the largest component of research funded under regional research. Expenditures on production research as a percent of the total expenditures on research funded under regional research was about 60 percent during the 1966-1979 period. Current dollar expenditures on production research fluctuated during the late 60's; declined from 1978 to 1979, but increased by 144 percent overall from 1966 to 1979. The constant dollar expenditures on production research varied during the fourteen-year period but declined by one percent overall from 1966 to 1979.

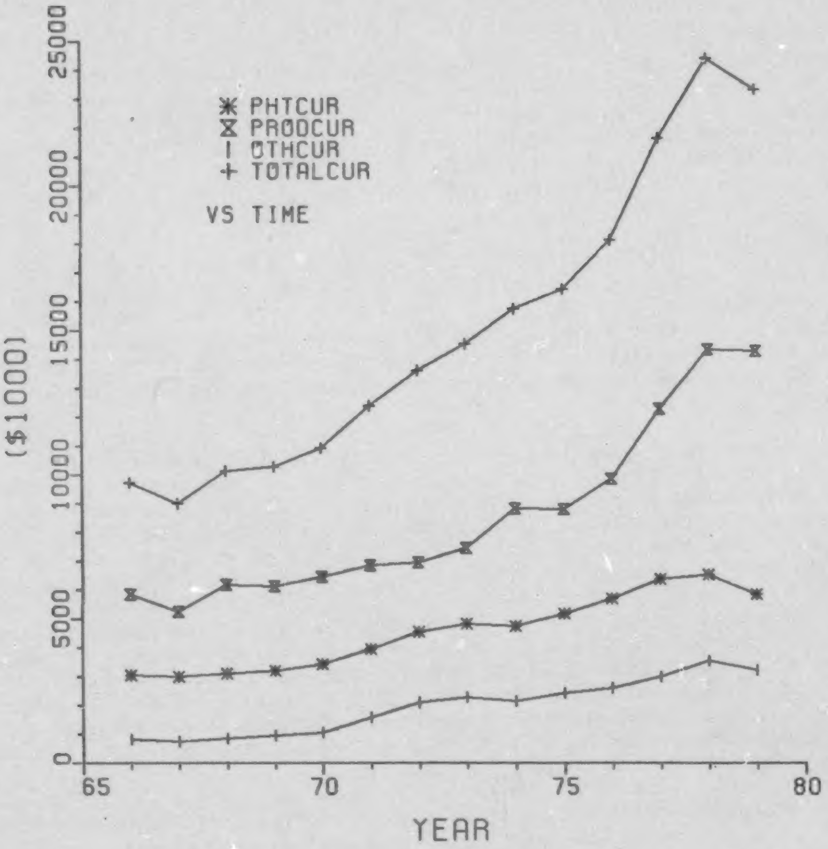
The current dollar expenditures on PHT research funded under regional research fluctuated during the 1966-1979 period and increased by 113 percent from 1966 to 1978. However, from 1978 to 1979 the current dollar expenditures on PHT research declined by eleven percent and hence the overall increase in current dollar expenditures from 1966 to 1979 was only 91 percent. The constant dollar expenditures on PHT research funded under regional research varied throughout the fourteen-year period and declined by 23 percent overall from 1966 to 1979, and much of that decline occurred during the last three years of the period.

The other research is the smallest component of the research funded under regional research. From 1966 to 1979 the proportion increased from eight to fourteen percent of total research funded under regional research. The current dollar expenditures on other research fluctuated throughout the 1966-1979 period but increased 288 percent overall from 1966 to 1979. The constant dollar expenditures also exhibit some fluctuations and increased by 57 percent overall from 1966 to 1979.

With few minor exceptions the expenditure patterns in the Northeastern, Southern, North Central, and Western Regions exhibited in Figures 71-78 were similar to the SAES total regional research expenditures. The following observations were characteristic of all four regions.

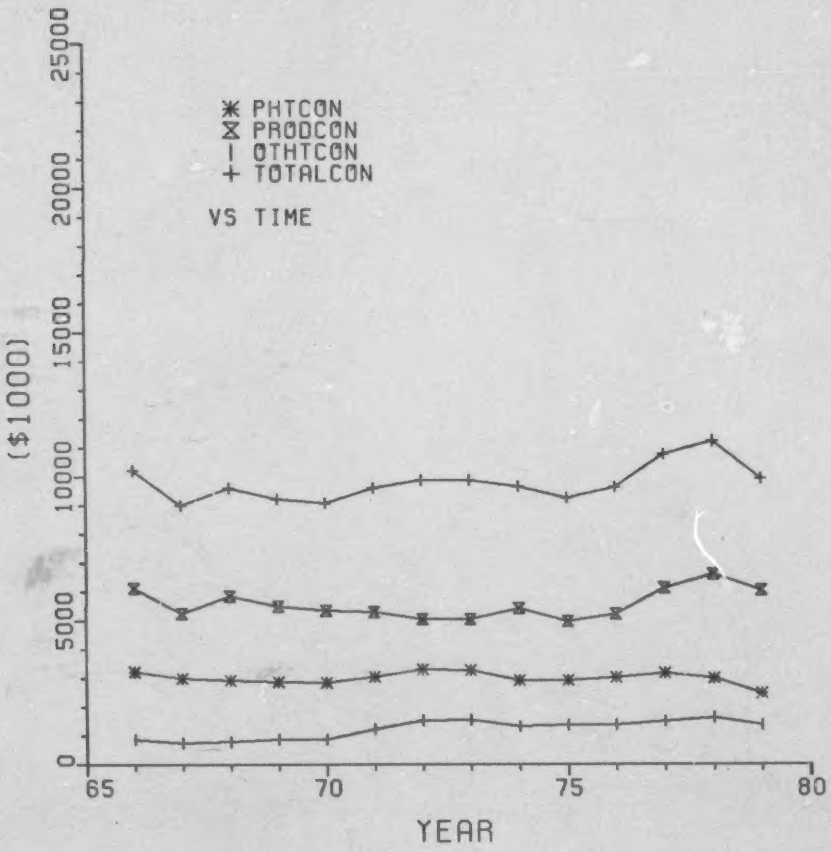
1. Current dollar expenditures on regionally funded agricultural research increased during the 1966-1979 period, but expenditures on all types of research decreased from 1978 to 1979.

FIGURE 69. TOTAL REGIONAL RESEACH FUNDS(RRF) FOR TOTAL, PHT, PRODUCTION, AND OTHER RESEARCH IN CURRENT DOLLARS, 1966-1979.



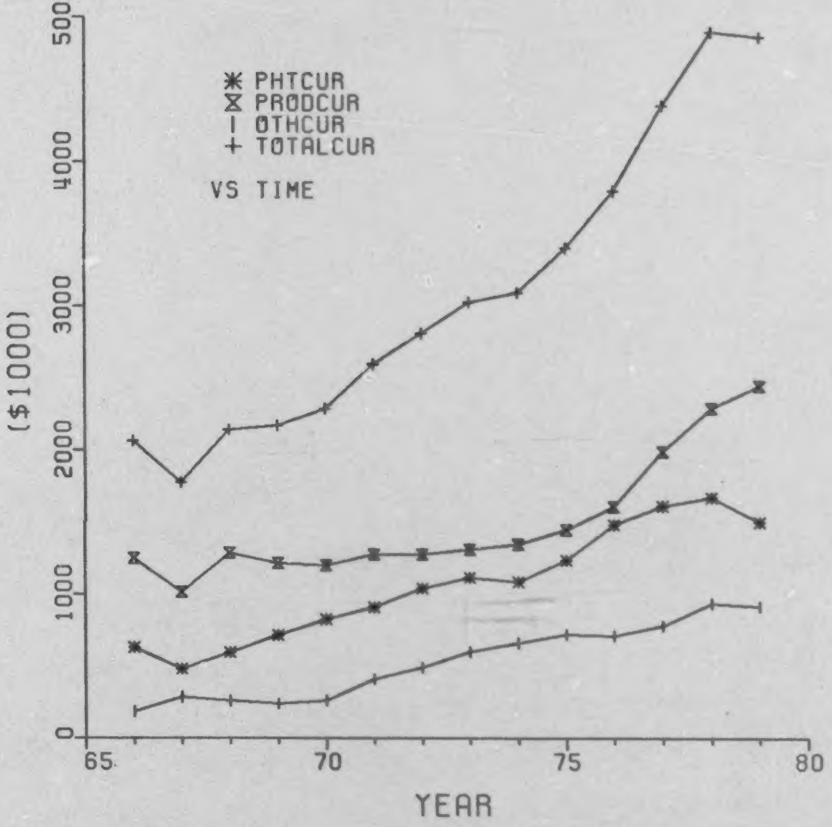
SOURCE: TABLE A-37.

FIGURE 70. TOTAL REGIONAL RESEACH FUNDS (RRF) FOR TOTAL, PHT, PRODUCTION, AND OTHER RESEARCH IN CONSTANT DOLLARS, 1966-1979.



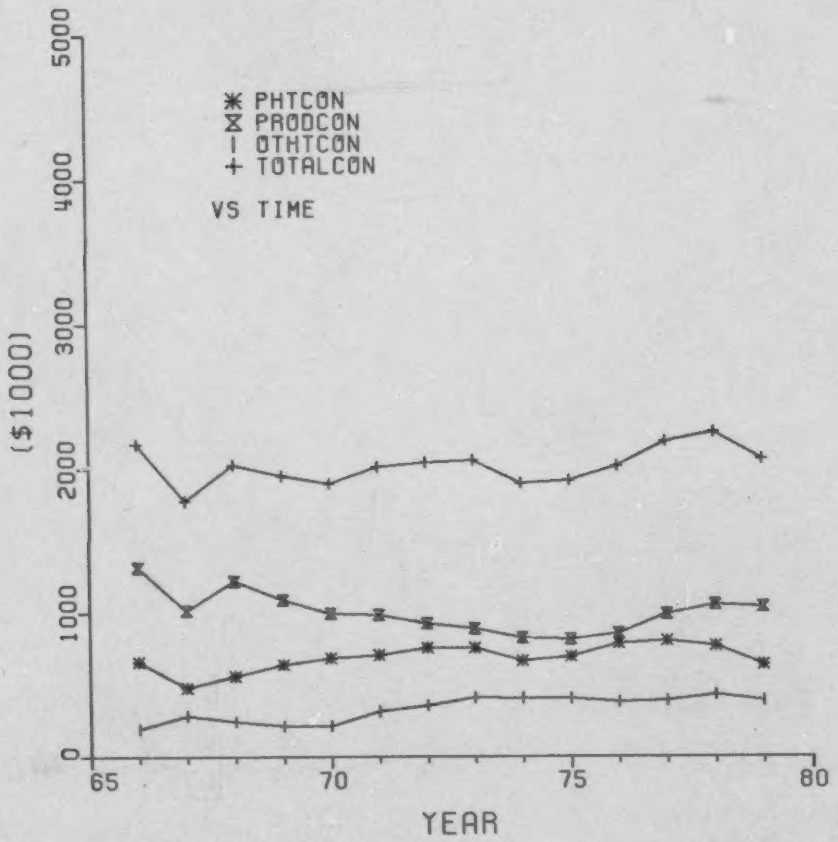
SOURCE: TABLE A-37.

FIGURE 71. SAES NORTHEAST REGIONAL RESEARCH FUNDS(RRF) FOR PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH IN CURRENT DOLLARS, 1966-1979.



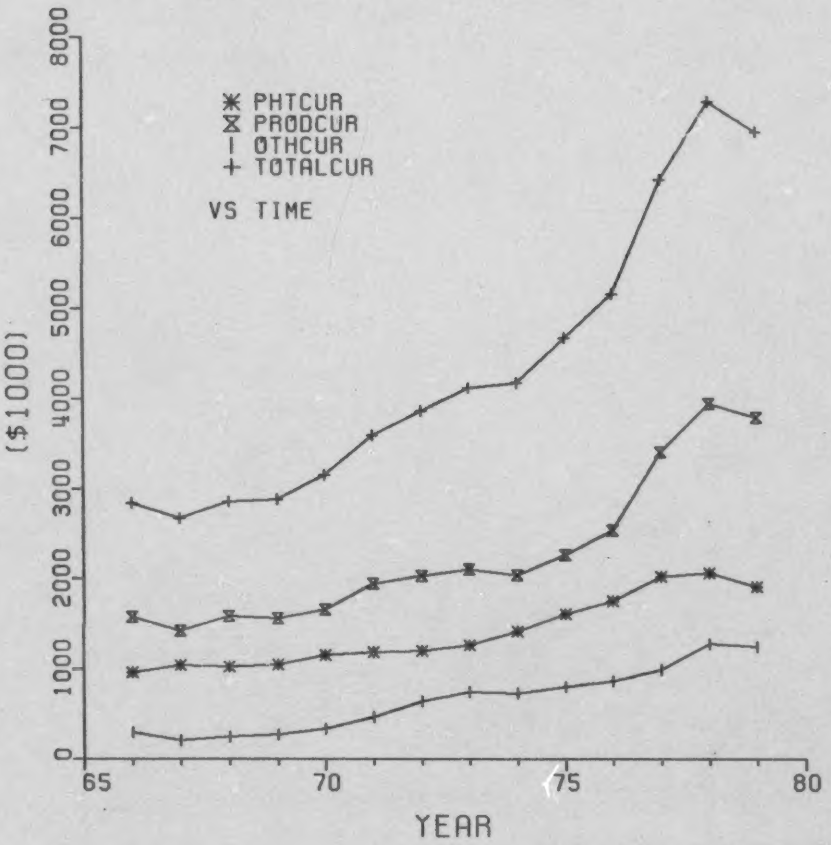
SOURCE: TABLE A-38.

FIGURE 72. SAES NORTHEAST REGIONAL RESEARCH FUNDS(RRF) FOR PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH IN CONSTANT DOLLARS, 1966-1979.



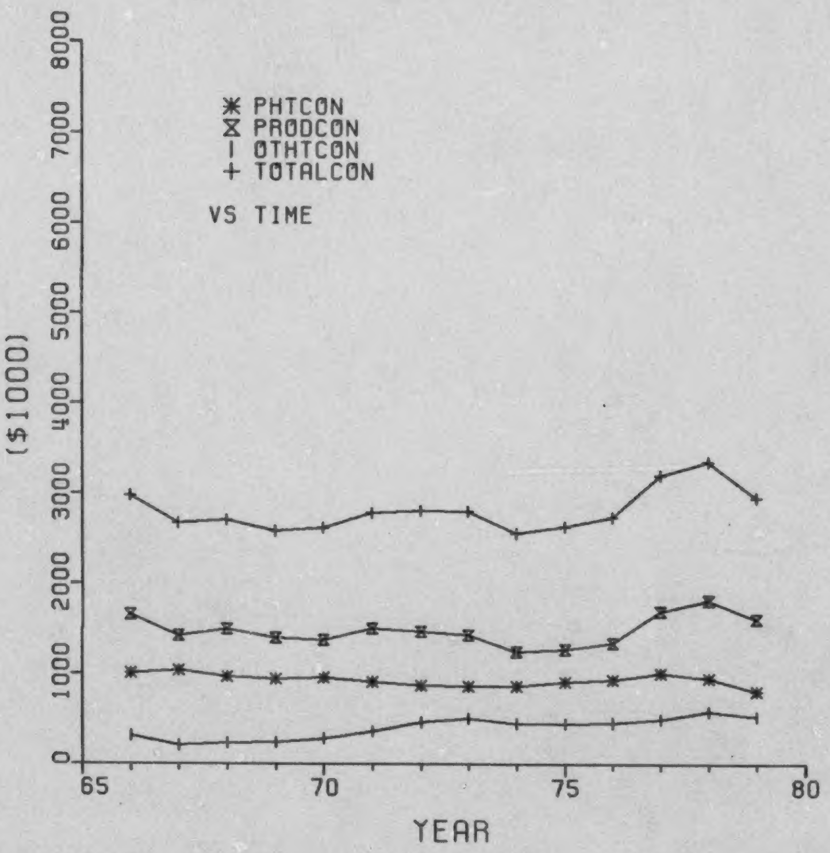
SOURCE: TABLE A-38.

FIGURE 73. SAES SOUTHERN REGIONAL RESEARCH FUNDS (RRF) FOR PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH IN CURRENT DOLLARS, 1966-1979.



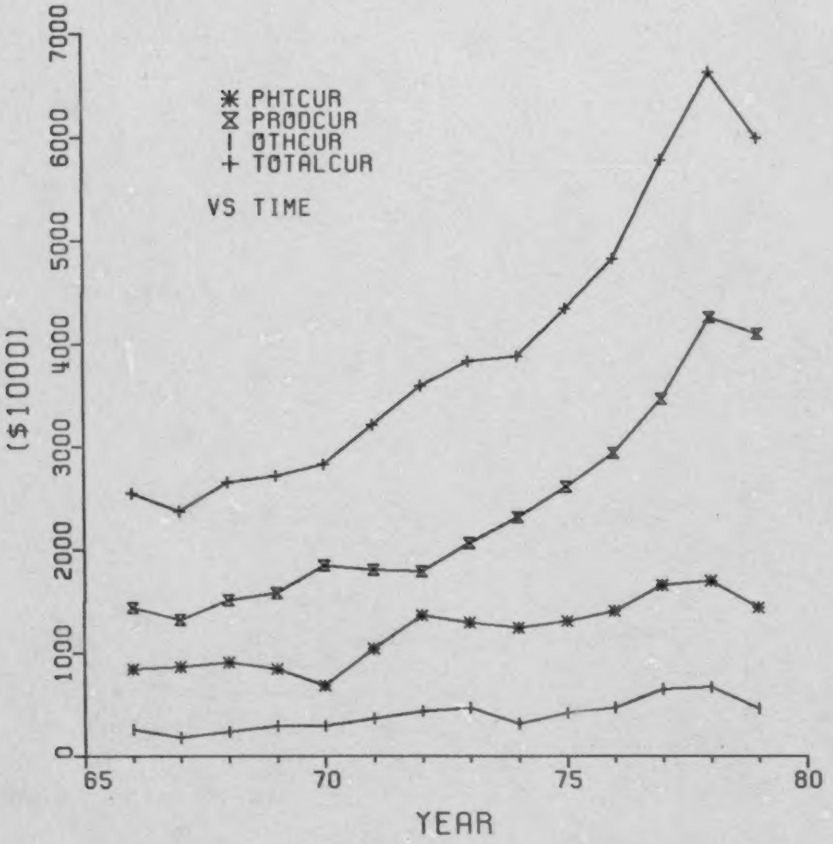
SOURCE: TABLE A-39.

FIGURE 74. SAES SOUTHERN REGIONAL RESEARCH FUNDS (RRF) FOR PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH IN CONSTANT DOLLARS, 1966-1979.



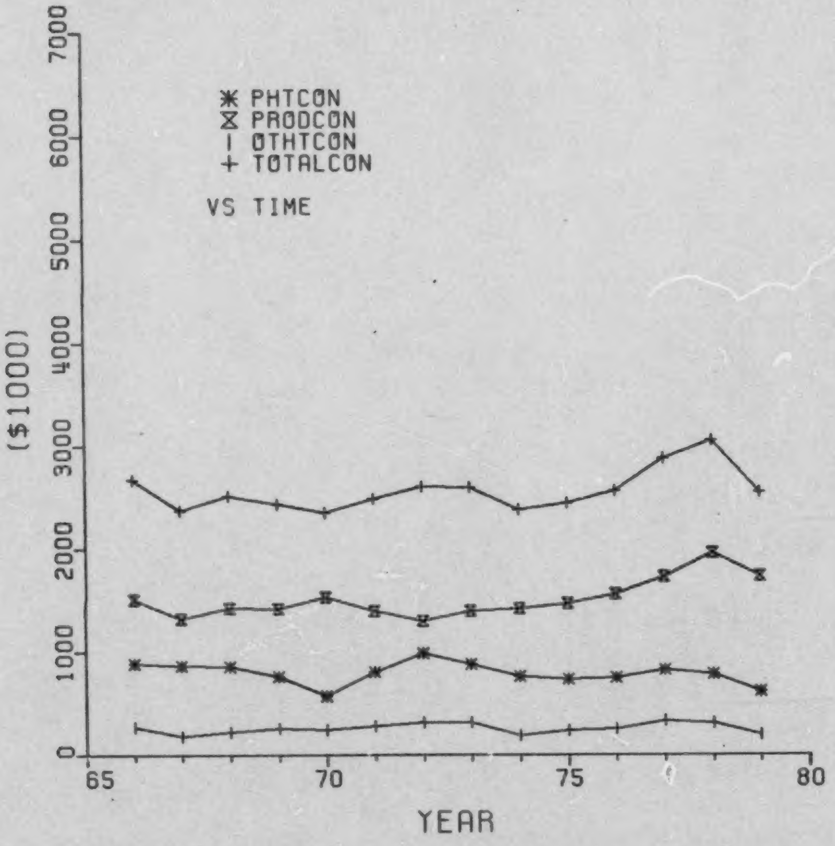
SOURCE: TABLE A-39.

FIGURE 75. SAES NORTH CENTRAL REGIONAL RESEARCH FUNDS(RRF) FOR PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH IN CURRENT DOLLARS, 1966-1979.



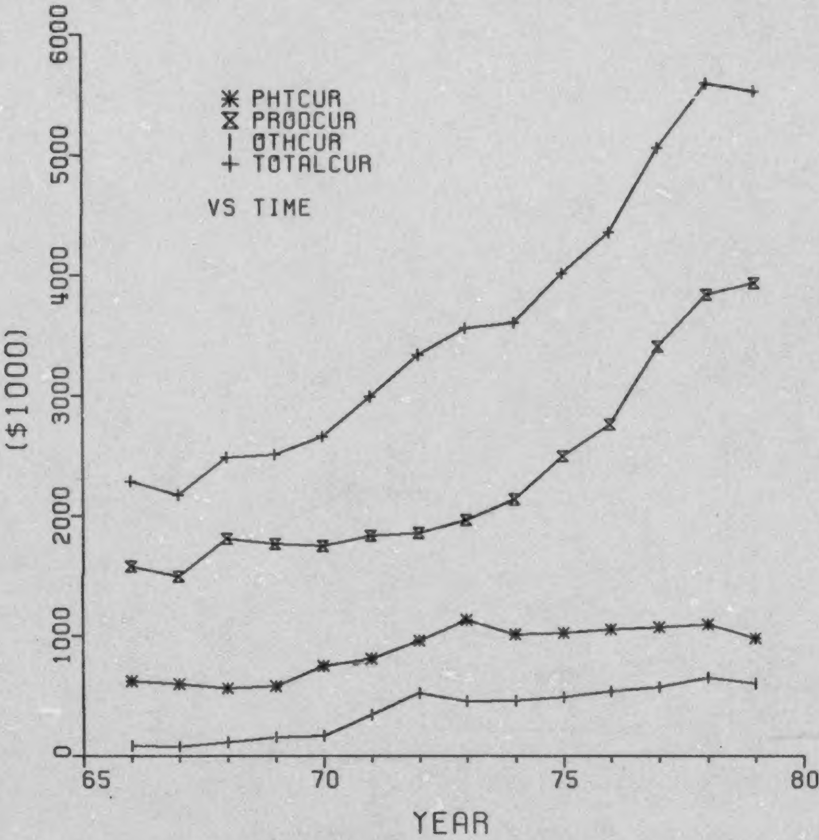
SOURCE: TABLE A-40.

FIGURE 76. SAES NORTH CENTRAL REGIONAL RESEARCH FUNDS (RRF) FOR PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH IN CONSTANT DOLLARS, 1966-1979.



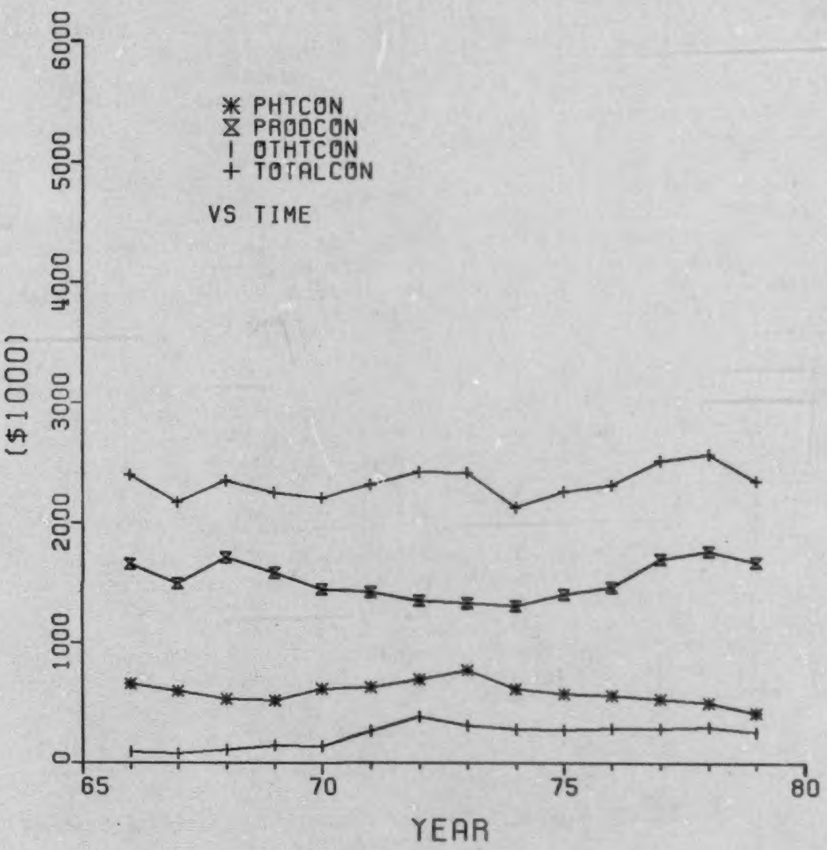
SOURCE: TABLE A-40.

FIGURE 77. SAES WESTERN REGIONAL RESEARCH FUNDS (RRF) FOR PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH IN CURRENT DOLLARS, 1966-1979.



SOURCE: TABLE A-41.

FIGURE 78. SAES WESTERN REGIONAL RESEARCH FUNDS(RRF) FOR PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH IN CONSTANT DOLLARS, 1966-1979.



SOURCE: TABLE A-41.

2. Constant dollar expenditures on research funded under regional research declined from 1966 to 1979.

3. Production research was the dominant component of expenditures on research funded under regional research. Current dollar expenditures on production research funded under regional research increased from 1966 to 1979. Constant dollar expenditures increased slightly from 1966 to 1977 in the North Central and Western Regions but declined slightly in the Northeastern and Southern Regions.

4. Other research was the smallest component of expenditures on research funded under regional research. The current dollar expenditures on other research increased in all four regions from 1966 to 1979. Constant dollar expenditures increased in the Northeastern, Southern, and Western Regions from 1966 to 1979, but declined in the North Central Region.

5. Current dollar expenditures on PHT research funded under regional research increased from 1966 to 1978 but decreased from 1978 to 1979. Constant dollar expenditures on PHT research funded under regional research declined from 1966 to 1979 with much of the decline occurring during the latter three years of the fourteen-year period.

State Appropriations

Current dollar expenditures on PHT, production, and other agricultural research from state appropriations and sales for the 1966-1979 period are presented in Figure 79 and constant dollar expenditures are presented in Figure 80. Current dollar expenditures from state appropriations and sales on all agricultural research increased steadily from $118 million 1966 to $457 million in 1979, which is an increase of 288 percent. The constant dollar expenditures increased fairly steadily from 1966 to 1979 and the overall increase was 57 percent.

Expenditures on production research were the largest component of total agricultural research expenditures from state appropriations and sales and in both current and constant dollars exhibit patterns similar to those for expenditures on all agricultural research. In 1966 expenditures on production research accounted for 78 percent of total agricultural research expenditures from state appropriations and sales and in 1979 for 75 percent. In current dollars the expendisures on production research increased by 261 percent from 1966 to 1979. The corresponding increase in constant dollars was fifty percent.

Current dollar expenditures on PHT research funded from state appropriations and sales steadily increased from $14 million in 1966 to $56 million in 1979. The overall increase from 1966 to 1979 was 299 percent. Constant dollar expenditures on PHT research increased steadily over the fourteen-year period and the overall increase from 1966 to 1979 was 62 percent. Throughout the fourteen-year period expenditures on PHT research were about twelve percent of the total agricultural research expenditures from state appropriations and sales.

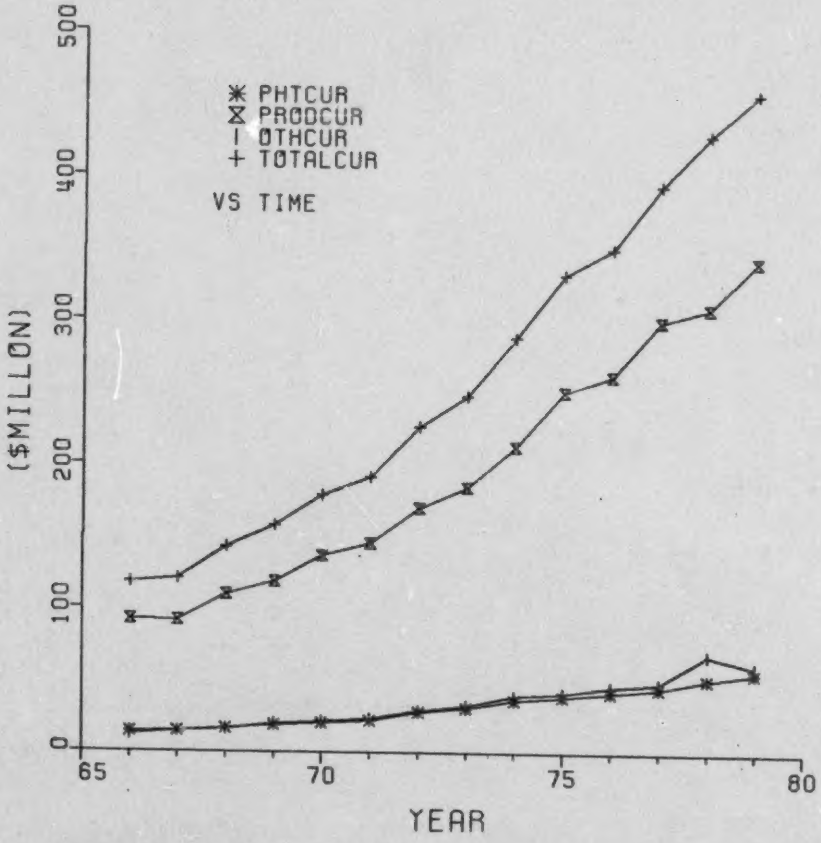
The patterns of expenditures on other research are similar to the patterns for PHT expenditures except from 1977 to 1978 when expenditures on other research increased nearly $14 million more than did expenditures on PHT research. In current dollars the expenditures on other research funded from state appropriations and sales increased 396 percent from 1966 to 1979. The corresponding increase in constant dollars was about 100 percent. Expenditures on other research were ten percent of total expenditures on agricultural research funded from state appropriations and sales in 1966 and thirteen percent in 1979.

Private Industry Sources

Current dollar expenditures on PHT, production, and other agricultural research at SAES from funds provided by private industry during the 1966-1979 period are presented in Figure 81, and constant dollar expenditures are presented in Figure 82. Current dollar expenditures from private industry sources on total agricultural research increased steadily from 1966 to 1969 for an overall percentage increase of 302 percent. The corresponding increase in constant dollars was 63 percent.

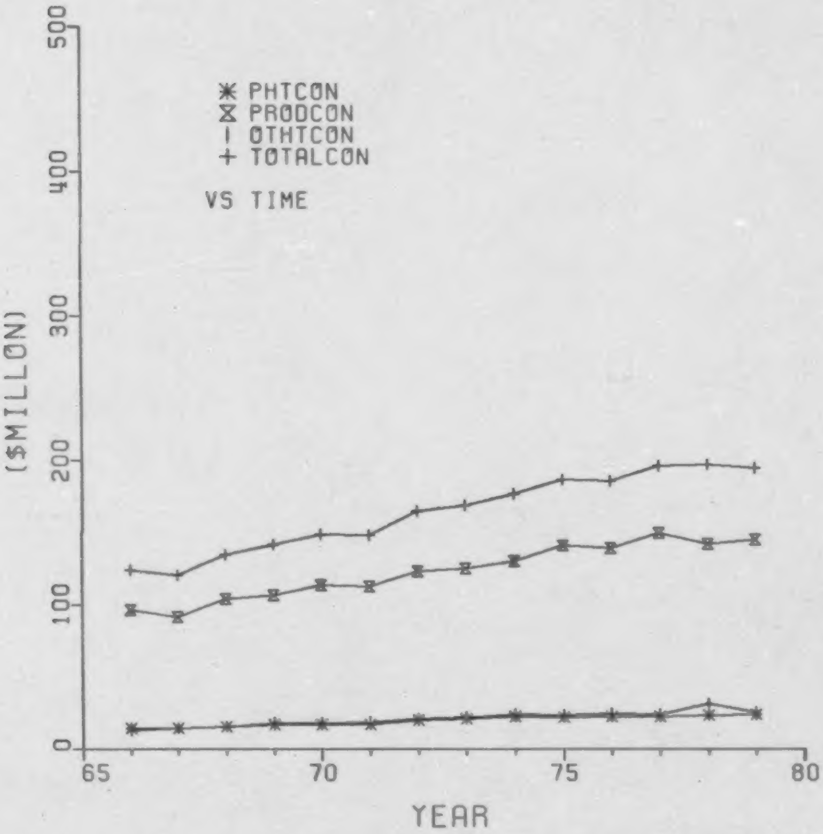
Expenditures on production research were the largest component of total agricultural research funds from private industry. Expenditures on production research were 72 percent of total research funds from private industry in 1966 and 68 percent in 1979. In current dollars expenditures on production research increased by 280 percent from 1966 to 1979. During the same period constant dollar expenditures increased by 54 percent.

FIGURE 79. SAES EXPENDITURES FOR PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH FROM STATE APPROPRIATIONS IN CURRENT DOLLARS, 1966-1979.



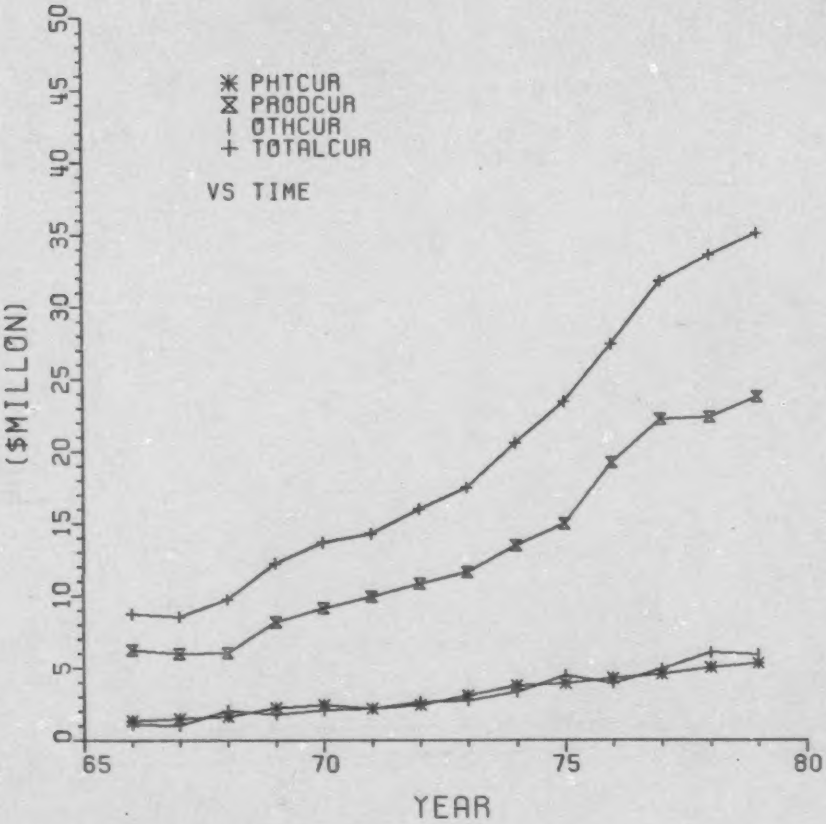
SOURCE: TABLE A-42.

FIGURE 80. SAES EXPENDITURES FOR PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH FROM STATE APPROPRIATIONS IN CONSTANT DOLLARS, 1966-1979.



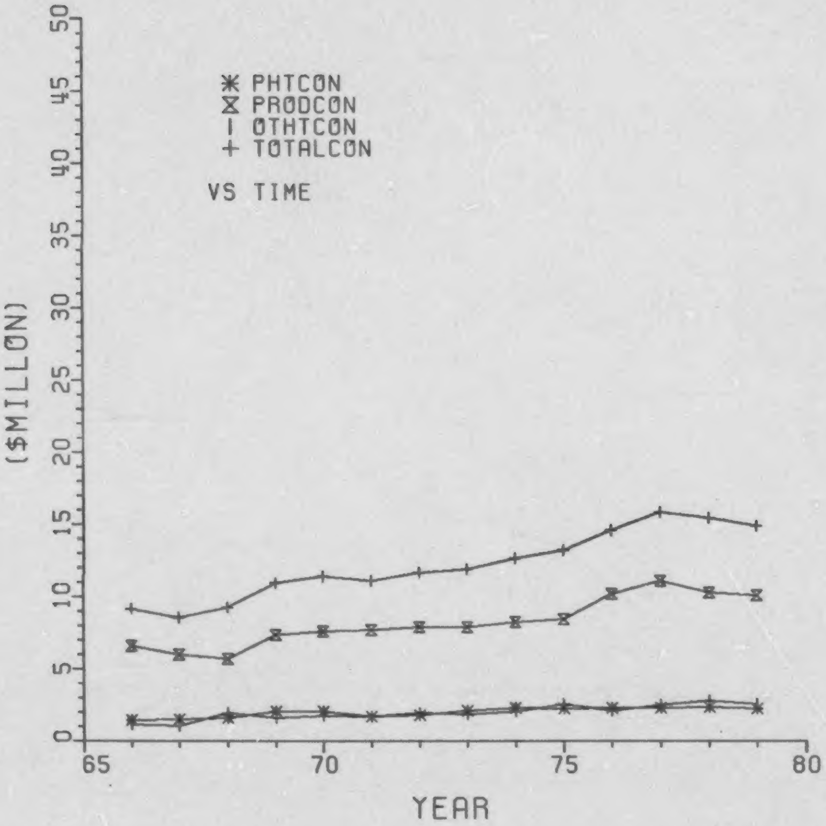
SOURCE: TABLE A-42.

FIGURE 81. SAES PRIVATE INDUSTRY FUNDS FOR PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH IN CURRENT DOLLARS, 1966-1979.



SOURCE: TABLE A-43.

FIGURE 82. SAES PRIVATE INDUSTRY FUNDS FOR PHT, PRODUCTION, OTHER, AND TOTAL RESEARCH IN CONSTANT DOLLARS, 1966-1979.



SOURCE: TABLE A-43.

Current dollar expenditures on PHT research varied during the 1966-1979 period but increased 288 percent overall from 1966 to 1979. In constant dollars the expenditures on PHT research increased by 57 percent from 1966 to 1979. Although these percentages are fairly high, the dollar amounts spent were quite small--the largest expenditure during the fourteen-year period was $5.3 million for 1979.

The expenditures on other research from private industry sources were about the same magnitude as those for PHT research. From 1966 to 1979 the current dollar expenditures on other research increased 450 percent, while constant dollar expenditures increased by 123 percent. The expenditures on other agricultural research were twelve percent of the total agricultural research funds from private industry sources in 1966 and 17 percent in 1979.

Determination of Priorities and Size of Investment in Agricultural Research

This section deals with the determination of research priorities and the budgeting process by the SAES and USDA. The roles of the individual scientist, administrators, clientele groups, and legislators in determining research priorities and allocation of resources among research areas are discussed. The process of setting research priorities and the budgeting process in the SAES are considered first, followed by a discussion of the same process in the USDA. The final part of this section consists of a brief summary of a few resource allocation models and experiments.

Priorities and Budgeting at the SAES

In the SAES, which includes eligible colleges of 1890 and Tuskegee, agricultural research priority setting and the budgeting process have to be considered at two levels. The first level is at the individual state agricultural experiment station. The second level is the national or combined state agricultural experiment stations level. This latter level is crucial because the priority setting and budgeting at that level is concerned with the allocation of federal funds to the states for agricultural research.

Individual station priorities and budgeting. Research planning and priority setting are continuous processes in each state agricultural experiment station and involve individual scientists, the director of the station, other administrators in the university, state legislators, and various clientele groups such as commodity groups, consumer groups, agricultural foundations, and agribusiness councils. In general each state agricultural experiment station has working relations and communications with producers, marketing firms, processors, and other interested parties. Mechanisms exist for these interested parties to provide inputs into the planning, priority setting, and budgeting processes. However, the mechanisms and procedures differ among the individual state agricultural experiment stations.

In individual state agricultural experiment stations the scientists conducting the research play a key role in determining research priorities and in determining the amount of funds that are allocated to various research areas. The scientists are the ones who ultimately identify the problems to be researched, write research project proposals, and formulate budgets which will allow the proposed research to be carried out in an effective manner. Also, it is usually the research scientists themselves who advise station directors with regard to research directions and who are involved in internal program reviews and longer range research planning. In establishing research priorities and identifying research problems, scientists usually take into consideration the guidance of the station director and other administrators at the university and utilize information from other scientists, extension personnel, and clientele or user groups with regard to emergence of problems, severity of effects of problems, and usefulness of solutions to problems. Information is communicated to research scientists by other scientists and administrators before project proposals are written and at the stage when the project is being reviewed by other scientists in the experiment station. Research projects which are to be funded by grants or other types of outside (soft) funds may receive a different type of review within the experiment station, but they must receive the approval of the director of the experiment station as well as receive approval through review by personnel of the granting agency or by scientists and administrators designated by the granting agency.

Since the individual scientist strongly influences what research will be done, the original hiring of a scientist is critical to priority setting. The kind of scientist hired will determine the kind of priorities that will be set and the type of research that will be done. Thus, the hiring decision is a critical one shared by the scientists in the particular unit; the head, chairman, or other chief administrator of the unit; the director of the state agricultural experiment station; and the dean or other chief administrator of the agricultural college. Relative to research priority setting and budgeting, the importance of the hiring decision cannot be overemphasized.

The director of the experiment station plays a critical role in research priority setting and budget allocation by providing guides and incentives to research scientists relative to alternative problems. The director of an experiment station is sometimes in a better position to view problems and research programs from a somewhat broader perspective. He can therefore suggest a direction of research programs from a somewhat broader perspective. He can therefore suggest a direction of research compatible with the goals and objectives of the station and with the importance of problems of agriculture from the director's perspective. The guides and suggestions which a director gives with regard to the importance of problems and for which he would provide research funds in most cases influence the priorities which individual scientists place on their own research programs. These guides and suggestions are sometimes communicated to the research scientist directly, while at other times they are communicated through a department or unit head or chairman. Regardless of how the signals are communicated, most research scientists prefer devoting their research efforts to problems which are viewed highly and supported by their peers and administrators. Undoubtedly there are exceptions but these are rare unless it is a case where the director's integrity and credibility are in question.

The director of the experiment station also plays a critical role in priority setting and funding of agricultural research by his support and approval of grants and other outside funds. Guides concerning what outside funds are compatible with the thrust and longer range goals of the experiment station are usually communicated to the individual research scientists. Approval of a project to be supported by outside funds explicitly or implicitly gives the research area a high enough priority to be acceptable as part of the station's overall agricultural research program. Alternatively, denial of a research proposal, or guides not to pursue funds for certain problems, clearly establishes a low priority for those problems.

Other administrators at state universities play a minimal role in establishing agricultural research priorities and in budgeting resources to agricultural research. Other administrators are subject to the same external pressures from various interest groups as is the director of the station, department head or chairman, and, in some cases, the research scientist. Other administrators at the state university are generally concerned with the broader goals and objectives and how the activities of the state agricultural experiment station fit the overall mission of the state university.

The roles that legislators play in setting agricultural research priorities and in the agricultural research budgeting process vary tremendously among states. In some states legislators simply do not get involved in the priority setting and budgeting process of the state agricultural experiment station. Occasionally some funds might be earmarked by the state legislature for research on a particular agricultural problem. In other states a formal structure exists by which members of the state legislature participate in determining which agricultural problems will receive support for research and the amounts of these supporting funds. In some states the state legislature has a subcommittee on agricultural research which not only has the responsibility of helping with the priority setting and budgeting process, but the subcommittee keeps itself informed about ongoing agricultural research by visiting branch stations and others parts of the state agricultural experiment station according to a formal schedule.

Clientele groups influence agricultural research priorities and the budgeting process through powers of persuasion and mainly through department heads or chairmen and research and extension personnel. Some state agricultural experiment stations have formal arrangements whereby representatives of clientele groups are advisors to research programs in some disciplines. This helps researchers to keep in touch with a particular industry and to be aware of problems facing the particular clientele group. At times clientele groups may let their feelings and positions with respect to priority of some problem be known through the director of the state agricultural station or higher administrators at the state university. Probably the greatest influence that clientele groups have is on key legislators who are responsible for the size of the state appropriations for agricultural research. Clientele groups are generally quite good at articulating their particular industry's or group's problems and needs and at influencing the appropriations for research on those particular needs and problems.

In terms of budgeting and allocations of funds, the research scientist and the department head or chairman have the most influence with regard to amounts of funds that will be allocated to particular problems. The individual researcher makes his case to the head or chairman of the department who in turn makes his case to the director of the agricultural experiment station. The department head or chairman operates from a base of the previous year in terms of salaries and operating supplies and makes the case for the level of funding needed to effectively continue ongoing research programs. Then he develops the priorities for the needed new programs and determines the support needed to effectively carry out these new programs. Since research projects are three to five years in duration, the priority setting and budgeting process is continuous and dynamic, and each year 20 to 33 percent of the research program in a department and at the state agricultural experiment station entails new high priority research projects.

Occasionally urgent problems or emergencies occur which require an immediate change in research priorities. There is no formal mechanism in the state agricultural experiment station for identifying and handling these kinds of situations, yet individual stations are able to respond quite effectively to the emergency situations. Usually identification of an emergency problem comes to a department--either to the head or chairman or to a scientist. Information about the emergency problem may come from industry or affected parties directly, or it may come through extension personnel in the field. Generally within a few days and sometimes within a few hours scientists are working on the problem. The first step is to determine what research information is already available and to quickly initiate research that will fill in the gaps and provide the additional information needed to solve the problem. Historically the SAES has an impressive record of responding to emergency and crisis situations.

SAES priority setting and federal budget process. In addition to the priority setting and research planning that occurs within individual state agricultural experiment stations and planning that is reported through formal administrative channels to USDA SEA/CR, there is a planning process by the Experiment Station Committee on Policy (ESCOP) Legislative Subcommittee relative to the federal research budget request for the SAES, Eligible 1890 Institutions, and Colleges of Forest Resources, Home Economics, and Veterinary Medicine. This subcommittee has two representatives from directors of state agricultural experiment stations in each of the four regions of the U.S. plus representatives from the 1890 Institutions and Colleges of Forest Resources, Home Economics, and Veterinary Medicine. This subcommittee prepares plans for future research budget requests based on the perceived needs of the groups they represent. Five-year projections of research plans developed for each individual state agricultural experiment station by its director, each director's feedback on the current status of the research budgets being developed, along with signals from the Secretary of Agriculture and OMB, and previous appropriations by Congress are used to identify high priority research areas and budget requests.

The ESCOP Legislative Subcommittee plays a helpful role in the priority setting and budgeting process concerned with the federal part of the SAES research budget. Decisions about priority research problems and amounts of supporting funds all begin with the ESCOP Legislative Subcommittee. The chairperson of this subcommittee is extremely important and extremely powerful because through his or her leadership, the research areas to be emphasized and the number of dollars allocated to support each research area are established. Throughout the budgeting process the individual directors have an opportunity to react to the recommendations of the ESCOP Legislative Subcommittee, and are invited to do so, but the initiative, responsibility and authority for developing the federal part of the SAES research budget request which is sent to the USDA rests with the ESCOP Legislative Subcommittee and its chairman. The ESCOP Legislative Subcommittee is influential from the viewpoint of the combined SAES in terms of molding the priorities and requests of the SAES research budget, but its recommendations do not reduce the autonomy of individual stations, and furthermore OMB and other federal agencies may choose to ignore its recommendations.

The ESCOP Legislative Subcommittee usually is considering, and concurrently working with, budgets for three years. Much of its effort is devoted to the development of the budget which will be the operating budget two years hence. The chairperson of the ESCOP Legislative Subcommittee is responsible for presenting and defending his or her budget request for that year through the hearings with OMB. An outline of the SAES federal budget process as developed by H. R. Fortman and modified to cover the steps for the FY 80 and FY 82 budgets is presented in Appendix B. This outline provides greater detail about the various steps in the priority setting and budgeting process relative to the federal portion of the SAES research budget requests. Much of the outline also pertains to the research budgeting procedure of the USDA.

Priorities and Budgeting at the USDA

Priority setting and budgeting take place at several levels within the USDA. Three levels important to the agricultural research budget are the teams organized around (1) decision units (DU), (2) agency heads, and (3) the Secretary and Chief Budget Officer. The priority setting and budgeting process in the USDA is complex and what follows is a brief summary of some of the key aspects of this process.

The budget request organized around DU's represents a key component of the agricultural research priority setting and budgeting process. The priority program areas identified for inclusion in the budget decision units are the result of a general consensus by administrators and grow out of planning activities and consultations with diverse research producing and using groups. As stated previously, the ESCOP Legislative Subcommittee has a voice in priority setting. National planning activities, national reports and studies, and advisory groups all influence final decisions on general program priorities. Staff personnel representing research scientists from their respective units or agencies play an important role in developing the focus of scientific thrusts within the priority program areas. This is one channel through which research scientists make their inputs into the priority setting and budgeting process. These research teams generally include liaison people from other agencies which are involved or have interest in particular problems and areas of research. The staff teams work closely with action and regulatory agencies to determine the research needs of these agencies. The end products of the staff teams are the proposed budgets for problem areas pertaining to the subject matter of the DU.

A second important level of priority setting and budgeting concerned with agricultural research entails the heads and key managers of interested and "sister" agencies. This includes agencies such as Science Education Administration (SEA), Economic, Statistical, and Cooperative Service (ESCS), Forest Service (FS), Soil Conservation Service (SCS), and Office of International Cooperative Development (OICD). Research areas of common interest which have received a high priority rating from two or more of these agencies are identified and then developed as themes of common interest and areas of cooperation in the development and presentation of the research budget.

The third and very crucial level of priority setting and budgeting relative to agricultural research is at the level of the Secretary of Agriculture. It is at the Secretary's level that priorities and proposed budgets from all agency heads, department heads, division heads, etc., are brought together and merged with the priorities and budgets from the Secretary's Office. At this level the guides from OMB and Congress are taken into consideration and the goal is generally to accomplish the proposed research with fewer dollars. The charge of the Chief Budget Officer is to cut the budget requests down to meet the guides given by OMB.

Priority setting in the USDA is a continuous process and priorities are used to develop research budget requests and plan changes in research efforts. In-house research scientists and specialists are important in determining agricultural research priorities and budgets in the USDA. The inputs of the research scientists and specialists are generally channeled through the staff teams organized around DU's or through agency managers and heads. Cooperators usually work closely with agency administrators and research scientists and channel their research priorities and budget suggestions through them.

Information about agricultural research priorities and budgeting from consumers, producers, scientific and technical societies, The Joint Council and Users Advisory Board, action and regulatory agencies, and other interested agencies may enter the priority setting and budgeting process anywhere from the individual in-house research scientist or specialist to the Secretary of Agriculture. The level at which the information enters the system depends upon the nature of the information and the relationship between those providing the information and personnel at various levels of the USDA budgeting process. Action and regulatory agencies generally make their inputs through the staff team agency administrators, whereas The Joint Council and Users Advisory Board channel their inputs through agency administrators or through the Secretary's Office. Policy level people in the Executive Branch and in Congress direct their suggestions regarding agricultural research priorities and budget primarily to the Secretary's Office and in some cases to agency heads and administrators. As the time to make final decisions about agricultural research priorities and budget approaches, information from all interested groups and individuals is integrated to develop research budget requests that will enable the USDA to carry out its mission effectively. The evaluation, review, and hearing process associated with budget requests extends over a period of approximately one and a half years, during which time the content of the requests may be altered significantly.

As in the SAES, there is no formal mechanism in the USDA for identifying and handling urgent problems and emergencies in agriculture. Yet, as in the SAES, the responsiveness to emergencies seems to work well. The process of changing priorities to accommodate an emergency situation generally starts with an involved administrator who indicates a need for help on a particular problem. The problem may have surfaced from in-house personnel or it may have come from producers, industry, extension personnel scientists in SAES, or personnel from the Animal Protection and Health Inspection Service (APHIS) which has scientists located in each state. As in the SAES the first step is to take stock of what research information concerning the particular problem is already available. Then actions are initiated to fill in the gaps and to generate the additional information needed to solve the problem causing the emergency situation. If in-house research capabilities to solve the emergency problem are not adequate, then the agency involved will make contact with researchers in state universities and SAES or with researchers in private industry. Communications are rapid and usually within a few days, and sometimes only hours, additional resources are allocated to research directed at the emergency problems.

Models for Allocating Agricultural Research Resources

Over the years a large number of models and procedures have been developed to aid the decision process with respect to research resource allocation. Many of the formal models have been developed and are being used to allocate funds for industrial and military research. Rather than considering a full spectrum of models, this review focuses on a few of the major models developed to deal with agricultural research in the U.S. This particular review benefits and draws heavily from two previous reviews dealing with issues of agricultural research allocation (Schumway[3] and Schuh and Tollini[4]).

A classification of these models for agriculture is based on several considerations. The first issue concerns the static vs. dynamic nature of the decision problem. The actions and reactions of the decision problem are assumed to take place either instantaneously or in an identifiable time path. A second consideration is the degree of certainty assumed to be associated with the decision problem. Simpler deterministic models assume perfect knowledge with respect to all events. Other models try to explicitly consider the fact that certain variables have a probability distribution of possible values (which may or may not be known) which are not under the direct control of the decision maker. The third consideration is the decision making environment which includes various influences such as interest groups or politics occurring within a decision body. Based on these criteria, the following set of research allocation models are reviewed. Since this is a summary description of each model presented, technical terms are not defined and the reader is referred to the references given in the model descriptions.

Scoring Models

Scoring models are relatively simple procedures to formalize the decision process of choosing a research portfolio. The evaluators (usually the scientists) conduct an evaluation of alternative research projects based on the contribution of each research project to a pre-specified goal, or set of goals. When dealing with a set of goals a weighting system needs to be invoked in order to arrive at a relative ranking of projects. Discussions of scoring models developed by Iowa State University, The National Association of State Universities and Land Grant Colleges and USDA (NASULGC-USDA), and the North Carolina State University have been made by Schuh and Tollini,[5] and Shumway[6] and are recapsulized here.

The Iowa Model.[8] The primary objective of this model was to improve the efficient use of research money spent at the state agricultural experiment station. Through a better selection of projects it was hoped to increase the value of research output and generate more funds for research. The impetus for developing this model began with an agreement by the involved administrators that a more formal method of resource allocation was needed. The group then decided upon a set of three major goals (growth, equity, and security) and attempted to attach a set of weights to these goals.

Using these goals and subgoals as a framework, the research effort of the station was divided into three major areas: commodity research, resource research, and agricultural management research. These three areas were further divided into 19 sub-areas comprising one or two products or resources, or aspects of agricultural and management research. A panel of experts was assigned to each of these areas and then asked to identify all research alternatives in each area. These panels developed a list of research projects supposedly representing the greatest contribution to the growth goals. In addition an estimated cost in terms of scientist years and funds was associated with each project.

In the next step, a second panel received the list of suggested research projects and evaluated them in terms of the second criterion, equity. This procedures was again repeated for the next goal of security. At each stage, each research project received a "grade" in terms of its contribution to each goal.

The subjectiveness of the grading system and the determination of appropriate weights for the set of goals are two obvious problems with this scoring model. Although the Iowa model is a static and deterministic procedure, some kinds of uncertainty can be handled by means of sensitivity analysis.

North Carolina Experiment on Research Priorities.[8] The North Carolina State model was organized in 1972 to help determine which Research Problem Areas (RPA's) should be given greater emphasis over the following five years. The committee's recommendations included reallocation of funding and scientists at the RPA and RPA sublevel.

The N.C. State experiment began with twenty task forces composed of an interdisciplinary team of research and extension personnel who reviewed the entire state research program. Each portion of the research program reviewed usually cut across interdepartmental lines.

In the second step of the process, eighteen panels of three scientists not associated with N.C. State reviewed the reports from the first level. In the next stage the 23 academic departments at N.C. State reviewed reports from the first two stages and presented a third set of five-year recommendations.

The three groups evaluated 90 RPA's after classifying them into four major research areas, each with different weighting criteria. These four major research areas were:

1. Biological Sciences and Technology
2. Animals and Plants
3. Environment and Natural Resources
4. Food, Fiber, People--Economics

A final set of criteria weights was developed through an interactive Delphi procedure involving a Research Planning Advisory Committee and the review committee members.

After review, project rankings were obtained from the scoring model. Results were reported according to average scores by all raters and average score minus one standard deviation of all raters. This second standard caused RPA's for which there was much sampling variation, or difference of opinion, to be ranked lower than the ordering achieved by the first standard.

The major advantage of the North Carolina State model, as with the other scoring models, is that it forces all people involved to formalize their reactions to various research proposals. Shumway's review[9] of an experiment with this model did indicate a rather low degree of association of scoring within and among groups.

The NASULGC-USDA Model.[10] The National Association of State Universities and Land Grant Colleges and the USDA jointly defined and implemented a systematic procedure for evaluating and allocating resources to agricultural research. The first step in the development of this system was the preparation of a general scheme for the classification of research. At this stage research was classified according to whether it was related to an activity, a commodity or resources, or a field of science.

The second step of the process was to classify all ongoing research at USDA and the SAES according to this scheme. Information was also developed on the number of scientist years and funds expended. The third step was to establish national goals for agricultural research. At this stage of the study the USDA adopted the Planning Programming Budgeting (PPB) system so that future work of the study needed to be made compatible with the "zero-base" budgeting type approach of the PPB.

The research program under study was then divided into six areas: (1) soil, (2) forestry, (3) horticultural crops, (4) field crops, (5) livestock and poultry, and (6) agribusiness and human resources. A review panel with representatives from the USDA, universities, private foundations, industry, and producer groups were set up for each area in order to subdivide the area into research problems and to provide estimates of the number of scientist years needed in the future.

The MARRAIS Model[11]

The Minnesota Agricultural Research Resource Allocation Information System (MARRAIS), which is classified as a multi-dimensional ranking model, is a computer-based, generalized structure for collecting and processing information on research allocations in situations characterized by a high degree of uncertainty. The primary purpose of MARRAIS is to generate benefit-cost measures of proposed research activities in order to facilitate a more efficient allocation of funds within an organization.

MARRAIS is characterized by separate components for the independent collection of information, the analysis procedure, and the specification and selection procedure. Within this system alternative research activities are first screened allowing certain activities to be presented to the research administrator for consideration and for collecting further information relevant to the decision making process. A more intensive analysis is then carried out on the collected data, such as a cost effectiveness or a benefit-cost analysis. The result of this exercise is a preordering of research projects based on market values. If there are any commonly accepted selection criteria, or particular criteria to be included in the evaluation, then a further "preordering" of alternative research can be made according to these additional criteria.

The information required by MARRAIS is of future, uncertain events, and is provided in association with probability distributions. Special attention is then given to the problems associated with achieving the most precise estimate of the flows over time of both costs and benefits of alternative research activities. Other significant factors that affect allocation decisions include the feasibility of achieving research objectives, the feasibility and cost of implementing new knowledge generated, and the degree of substitutability and complementarity among alternative research activities. Methods for obtaining estimates of all of these factors are followed and used to prepare subsequent estimates of various experiment station projects.

The analysis stage includes generating "consensus" estimates of the various benefit, cost, and feasibility factors which are arrived at through the use of various weights for each of the factors.

The final step is the reporting of the results in a form useful to research administrators. A major difficulty in using MARRAIS is the potentially large variation in estimates of the relevant variables. However, a sensitivity analysis using these variables can still provide useful information to the decision process.

Cartwright Model[12]

This model focuses on the research allocation decisions within a department of agricultural economics. Two types of decision problems are analyzed: the choice of research area and the selection of a research portfolio. To operationalize, Cartwright's model requires information on (1) the amount of time each researcher has available to input to a new project in a given period, (2) the amount of time each researcher has available to divert to a new project in a given period, (3) the amount of funds that a new research area would bring to a department, and (4) the number of new staff positions created in a given time period if a certain procedure were adopted. With this information and a statement of the staff preference function, the allocation to research areas is solved as a non-linear integer programming problem.

The job portfolio selection involves a simultaneous evaluation and selection of all research jobs once each quarter. Research is classified according to whether it is dissertation or non-dissertation research and again by whether it is funded by experiment station money or by outside research contracts. The information required to run this portion of the model includes (1) the amount of time required from each staff member by each alternative job, (2) the annual expenditure required by each job, (3) the amount of uncommitted time, by time period, for each researcher, and (4) the annual departmental budget by classifications. Next the departmental goals need to be formulated into an objective or satisficing model. Again, an optimization model could be used to determine an "optimal" allocation of projects.

Although this model presents a rigorous and quantitative conceptual method for resource allocation, further development has not been made toward putting the procedure into actual operation.

Castro and Schuh Model[13]

The major characteristic of the Castro and Schuh model is the emphasis it gives to both growth and distributional effects of research and the resulting technological change. Using concepts of producer's and consumer's surplus, functional distribution of income, and two-sector models of general equilibrium, this model analyzes impacts on key parameters in order to assess the effects of research on given products of a given country. Four goals are established for a research program: (1) to increase the net income of the agricultural sector; (2) to increase employment and income of workers in the agricultural sector; (3) to increase consumer welfare through lower real food prices; and (4) to maximize the contribution of the agricultural sector to growth of the overall economy.

This model depends primarily on secondary data so that the burden on scientists and administrators in terms of supplying difficult estimates is minimized. This model makes no explicit use of probabilities of success; implicitly, the probabilities are assumed to be equal. The choice of different probability levels is an empirical question that the authors leave up to further research.

Alternative Methods of Resource Allocation Decision Procedures[14]

A variety of less structured mechanisms for allocating research funds were also reviewed. Important criteria considered in this approach are:

1. How quickly can judgments be obtained using a technique?

2. What processing costs are incurred?

4. How many opinions are listened to?

5. How does the technique affect the risk of a bad decision?

6. What types of information can be obtained from the process?

Applying these criteria, a set of loosely defined procedures for ranking projects was developed.

One dimensional ranking methods. A variety of techniques such as paired comparisons, successive ratings, successive comparisons, and Q-sorts are used to make systematic comparisons of a group of a few projects.

1. Q-sorts--projects are divided into hierarchical categories on the basis of anticipated benefits.

2. Paired comparisons--projects are preordered and all possible pairs examined to provide an ordinal ranking of projects with higher benefits. After the ordinal ranking, successive comparisons are used to establish a relative cardinal ranking.

3. Successive comparisons--benefit values are refined by comparing the value of a high benefit project to lower ones until the number of projects in a portfolio is reduced to a single preferred high benefit project.

4. Dollar metric--absolute benefit cost ratios are computed and paired comparisons are made to identify preferred projects. Projects are preferred on the basis of a comparison of how much the cost of a preferred project could increase before an alternative is chosen, with a determination of how much a least preferred project's cost could decrease before it is preferred. This base figure permits the specification of anticipated benefits in dollar terms.

Group determined measures of benefits. After eliciting individual subjective rankings, the decision maker still has the problem of determining which person to listen to and how to process multiple opinions. A variety of options are used.

1. "Committee or round table"--a group meets, airs opinions and arrives at a "group opinion."

2. "Chain of command"--an opinion is formed through successive interactions between supervisors and subordinates along a chain of command.

3. "Delphi" approach--this approach consists of a series of individual interrogations to a group of experts interspersed with information and opinion feedback.

Multi-dimensional ranking method. These approaches incorporate measurements for each dimension of project benefits and provide additional sets of information to assist administrators choose among decision options. Often, no effort is made to provide an overall project rank. Included in this category are:

1. The Minnesota Research Resource Allocation and Information System (MARRAIS) which was discussed earlier.

2. Benefit contribution model--the overall goals of an organization are divided into independent, mutually exclusive objectives which are then weighted according to importance. Total benefit of a project is computed from product summation.

These multi-dimension approaches are also compatible for use with group and comparative methods.

Concluding Observations

The various models discussed in this section have attempted to formalize systematically the procedure for establishing priorities on research projects and for allocating funds and other resources to the research projects. Even though the models rely on some rather rigorous quantitative techniques, each ends up utilizing some judgmental data such as weights assigned to projects, ranking of projects, paired comparisons of projects, subjective probabilities of success in achieving the project results. The use of judgmental data detracts from the rigor of the models and makes them less attractive. Second, each of the models requires substantial time from scientists, administrators, and/or other personnel familiar with the problem areas being considered in the research projects. Thus, the cost of using these models on a continuous basis has diminished their wideapread use. Although parts of various models may be in use at various research institutions, it is doubtful if any of the models are being used in their entirety on a continuous basis.

Additional Considerations

Three topics related to financing agricultural research, but which usually receive little attention, are discussed briefly in this section. The topics are concerned with duplication of agricultural research, alternative measures of impacts of agricultural research and alternative approaches for financing agricultural research. The latter is concerned more with criteria for allocating agricultural research funds than it is with alternative approaches for acquiring funds for agricultural research. The discussion on all three of these topics is conceptual in nature.

Duplication of Agricultural Research

Duplication is concerned with repeating research completed in the past or conducting research which is already being done at another state agricultural experiment station, in USDA agencies, or in private industry. There are two situations for which duplication of research is meaningful and necessary.

1. A certain amount of duplication of research is needed for verification or disapproval of discoveries and research findings. Usually repeated results are needed before a discovery or research finding has credibility. This type of duplication is a necessary part of the research and development process.

2. At a particular location, i.e., a particular state agricultural experiment station, federal agency, or private company, certain research may be conducted because of its interaction with other research, extension, and educational activities even if it is duplication research being done elsewhere. This type of research may be an integral part of a system and its value has to be assessed through its contributions to the other components of the system. For example, certain types of research may be conducted to support graduate programs and extension programs. This type of research may be tantamount to these programs and will be conducted irrespective of duplication of research elsewhere.

Resources devoted to these types of duplicative research may yield greater marginal benefits and have greater impacts than they would if allocated to agricultural research which was not duplicative or even if allocated to other uses rather than agricultural research.

The amount of duplicative research being conducted is limited. Only a limited amount of verification is needed and only certain aspects of extension and educational programs need the types of supporting research which would duplicate research being done elsewhere. A natural deterrent to the conducting of this type of duplicative research is that there is little or no peer credit and rewards to scientists engaged in such duplicative research.

There is some research which does not exactly duplicate other research but which is similar enough that it appears to duplicate other research. An immediate issue is to what degree the similarity between two research efforts constitutes duplication of research. Two research efforts may be addressing themselves to the same problem, have similar objectives, and utilize similar research procedures, but the research is not conducted under different conditions which affect the problem and the solutions. The two research efforts are duplicative to some degree, but what becomes crucial is whether the factors which differ between the two situations really affect either the solution or the conclusions and implications in a significant way. If not, then clearly there is duplication and if the conclusions and implications are affected, then complete duplication does not exist, although some may exist. Furthermore, this apparent duplication is also a necessary part of the research and development process in that results from one research effort need to be verified under different conditions or adapted to another environment. In addition, when assessing this type of agricultural research which appears to be duplicative, consideration must again be given to the potential interaction with other research, other extension, and educational activities. Because of the nature of the discovery and solution process in agricultural research, the spill-ins of information from other closely related research and the spill-outs from the particular research to other closely related research are crucial and may lead to substantially greater benefits from both research efforts.

Before judgment is passed on the merits of agricultural research which appears to duplicate or actually duplicates research being done elsewhere, the impacts of this research on other research, other extension, and educational programs need to be considered. If the impacts in terms of marginal benefits or marginal returns to investment in this type of research exceed those which could be obtained if the same amount of funds were allocated to other research or other uses, then from a social viewpoint it would be beneficial to fund the duplicative or apparently duplicative agricultural research. In fact it would be economical to fund such research to the level where the incremental benefits from the last dollar invested in the duplicative or apparently duplicative research is equal to the marginal benefit which could be obtained from investing that dollar in other research or other uses. This would identify an equilibrium situation and an optimal level of funds for duplicative or apparently duplicative research.

This discussion should not be misinterpreted as an indiscriminate support of duplication in agricultural research. The main purpose of the discussion is to point out that a role exists for some duplication and for some research which appears to duplicate other research and that the benefits from these types of research may be high. More attention needs to be devoted to measuring and analyzing the benefits and returns to investment in these duplicative and apparently duplicative types of agricultural research. Also, scientists need to be cognizant of other research with similar thrusts which appears to be duplicative. These researchers need to carefully identify conditions which may be different and the types, magnitudes, and distribution of benefits which might be expected from this research.

Alternative Measures of Impacts

Most of the research concerned with measuring the impacts of agricultural research have focused on either total or production oriented research and the impacts that this research has had on productivity, agricultural output, or value of agricultural output at the producer level. Research with this particular focus has an impressive track record with respect to identifying significant effects of agricultural research and large rates of return to investment in agricultural research. But the effects of all agricultural research are not to increase agricultural productivity, agricultural output, or value of agricultural output, nor is the output of all agricultural research measurable and priced in the market place. A few alternative measures which merit consideration are discussed briefly in the following paragraphs.

In this report considerable attention is devoted to post-harvest technology and marketing research which has its primary impacts after harvest and prior to consumption. Except for the portion of agricultural marketing research concerned with inputs used in production, measuring output or value of output at the producer level or measuring agricultural productivity at the producer level does not even consider the changes which would be expected to occur from PHT type of research. To measure the effects of PHT research including agricultural marketing, focus will have to be on characteristics which reflect changes at the various storage, processing, and distribution levels from harvest to consumption. This suggests that focus is needed on attributes such as quality of foods, nutritional improvement, and value added. None of these are very meaningful in an aggregate agricultural output framework which suggests that if headway is to be made with respect to these types of characteristics, research will have to focus on individual commodities and selected foods processed from the commodities. Furthermore, there is not a concise common unit of measurement for characteristics such as quality of food or nutritional improvement.

These characteristics are not priced in a market; thus some severe measurement problems exist. However, the value added concept does offer some encouragement as an approach for assessing various types of PHT research. The changes in the value of a commodity or food product as it moves through the marketing channel can be assessed for at least some commodities by using available data on value added and marketing margins. Also, the PHT research directed at the various levels of the marketing channel can be identified. Hence, measuring the impacts of PHT research on changes in value added across the entire marketing channel and at various levels of the marketing channel is not only a challenging area of inquiry but the research is likely to be quite productive and useful.

Agricultural research on non-production areas such as rural development problems, environmental quality problems, resource conservation problems, etc., are not likely to have their impacts captured in changes in agricultural productivity and output at the producer level. If impacts of these types of agricultural research are to be captured, attention will need to be devoted to quality measures and measures of well being. Also, attention on cost effectiveness of investment in these types of research merits consideration.

Supplemental Approaches for Financing Agricultural Research

There are two aspects of financing agricultural research which are briefly discussed. The first deals with financing various areas of agricultural research within total agricultural research. Thus, it deals with the allocation of funds to various research areas. The second deals with acquisition and allocation of funds for agricultural research. Both are based on the simple idea that maybe the marginal benefits of and marginal rates of return to agricultural research ought to be considered in allocating funds to agricultural research.

Although most of the research on measuring the impacts of agricultural research has been concerned with aggregate agricultural research at the national level, research concerned with the impacts of research on individual commodities and analyses of regional impacts of agricultural research suggest that differences in impacts exist. These differences suggest that funds allocated to different types of agricultural research do not all yield the same marginal benefits nor the same returns to investment. This also suggests that greater benefits and returns could be obtained if more funds were allocated to research areas and geographical areas yielding greater benefits and returns to investment in agricultural research. Furthermore, research information is not confined to commodity lines nor geographical areas, but tends to spill over among commodities and among geographical regions. Some regions may have greater capacity to import research results from other regions, while other regions may have a comparative advantage in generating and exporting research results. First, more research is needed to estimate the marginal benefits and rates of return to investment in agricultural research among commodities and commodity groups and among the geographical regions of the U.S. Second, these results can then be used to more effectively allocate the limited resources for agricultural research among commodities, commodity groups, and geographical regions of the U.S.

The second aspect of financing agricultural research deals with the acquisition of additional funds and allocation of funds for agricultural research. It is predicated on a simple notion that agricultural research does generate some benefits which accrue to some individuals or some part of society. The amount and value of those benefits depends upon whether the research is basic or applied, the possibility of resultant patents, economies of scale in the research, and the time period being considered. The longer the time period, the more widely dispersed are the benefits and the more they accrue to consumers in general. But for shorter time periods and for particular types of research, specific benefits accrue to a few rather clearly identifiable individuals or firms. Certain mechanical harvesting innovations are a good example. In such cases it would appear that the beneficiaries of such research should finance all or part of the research. This would require estimating the magnitude and distribution of such benefits and soliciting financial support from the beneficiaries before the research was ever conducted. This is an area that deserves additional attention.

The notion of funding various areas of agricultural research according to marginal benefits or rates of return on investment may have some merit in allocating funds among departments and agencies of the federal government as well as among research and other programs within an agency. Agriculture has made an effort to measure the impacts of its research program and to estimate benefits and returns to investment in its research program. If the research and other programs for other departments and agencies within the federal government were analyzed in a comparable way, the resulting marginal benefits and rates of return to investment would provide some guides for allocating resources among departments or agencies and among programs within departments or agencies. This kind of information, along with alternative objective functions could be used to systematically allocate funds between research and other programs in agriculture, between agricultural research and other types of research and between various programs among departments or agencies of the federal government.

FOOTNOTES

[1] This definition is similar to the one given by Dr. Richard Aldrich, "U.S. Food and Agricultural Research, A Background Report," Food and Renewable Resources Program, Office of Technology Assessment, U.S. Congress, February, 1980. Various types of storage include on farm or ranch storage as well as storage at other levels in the marketing channel.

[2] The research goals evolved from the long-range study of agricultural research published in October, 1966, under the title "A National Program of Research for Agriculture."

[3] Shumway, C. Richard, "Models and Methods Used to Allocate Resources in Agricultural Research: A Critical Review," Resource Allocation and Productivity in National and International Agriculture Research, ed. Thomas N. Arndt, Dana G. Dalrymple, and Vernon W. Ruttan, University of Minnesota Press, Minneapolis, 1977, pp. 436-457.

[4] Schuh, G. Edward and Tollini, Helio, "Costs and Benefits of Agricultural Research: State of the Art, and Implications fot the CGIAR," paper written for Consultative Group on International Agricultural Research, April, 1978.

[5] Ibid.

[6] Shumway, op. cit.

[7] Schuh, op. cit.

[8] Schuh, op. cit.

[9] Shumway, op. cit.

[10] Williamson, J. C., Jr., "The Joint Department of Agriculture and State Experiment Stations Study of Research Needs," Resource Allocation in Agricultural Research, ed., Walter L. Fishel, University of Minnesota Press, Minneapolis, 1971, pp. 289-301.

[11] Fishel, Walter L., "The Minnesota Agricultural Research Resource Allocation Information System and Experiment," Research Allocation in Agricultural Research, ed., Walter L. Fishel, University of Minnesota Press, Minneapolis, 1971, pp. 344-381.

[12] Schuh, op. cit.

[13] Schuh, op. cit.

[14] Shumway, op. cit.

APPENDIX A

SOURCE TABLES

TABLE A-1 AAUP INDEX OF PROFESSORS SALARIES, IMPLICIT DEFLATOR FOR GOVERNMENT PURCHASES OF GOODS AND SERVICES, CONSUMER PRICE INDEX(CPI), AND PRODUCER PRICE INDEX,1960-1979.

YEAR	AAUP SALARY INDEX	IMPLICIT GOVT. INDEX	WEIGHTED DEFLATOR INDEX a/	CONS PRICE INDEX	PROD PRICE INDEX
1960	68.9	79.9	72.2	88.7	94.9
1961	72.1	81.5	74.9	89.6	94.5
1962	75.9	84.2	78.4	90.6	94.7
1963	79.2	86.2	81.3	91.6	94.5
1964	83.5	88.1	84.9	92.9	94.7
1965	88.3	90.9	89.1	94.5	96.6
1966	93.9	95.3	94.3	97.2	99.8
1967	100.0	100.0	100.0	100.0	100.0
1968	107.4	105.6	106.9	104.2	102.5
1969	113.3	111.5	112.8	109.8	106.5
1970	119.6	120.5	119.9	116.3	110.4
1971	123.7	129.1	125.3	121.3	113.9
1972	129.1	137.7	131.4	125.3	119.1
1973	135.1	147.2	137.0	133.1	134.7
1974	143.1	163.1	148.0	147.7	160.1
1975	151.3	177.5	158.0	161.2	174.9
1976	157.0	188.3	165.2	170.5	183.0
1977	164.8	200.7	174.2	181.5	194.2
1978	171.3	217.3	184.9	195.4	210.7
1979	176.5	235.3	194.0	217.0	236.2

a/ THE INDEX FOR DEFLATING AGRICULTURAL RESEARCH EXPENDITURES IS EQUAL TO(.7) TIMES THE AAUP INDEX OF PROFESSORS SALARIES PLUS(.3) TIMES THE IMPLICIT DEFLATOR FOR GOVERNMENT PRUCHASES OF GOODS AND SERVICES.

TABLE A-2. TOTAL RESEARCH EXPENDITURES AT SAES, USDA, AND COMBINED SAES AND USDA IN CONSTANT AND CURRENT DOLLARS 1966-1979.

($1000)

	SAES		USDA		COMBINED SAES+USDA	
YEAR	RES EXP CURRENT $	RES EXP CONSTANT $	RES EXP CURRENT $	RES EXP CONSTANT $	RES EXP CURRENT $	RES EXP CONSTANT $
1966	205215	215336	153084	160634	358299	375970
1967	207675	207675	165424	165424	373099	373099
1968	242687	229817	159150	150710	401837	380527
1969	259292	232549	163865	146964	423157	379513
1970	282101	234109	176896	146802	458997	380911
1971	300224	232552	197084	152660	497308	385212
1972	346942	251955	224308	162896	571250	414851
1973	378658	257240	236291	160524	614949	417764
1974	430609	264015	240183	147261	670792	411276
1975	490054	276087	265604	149636	755658	425723
1976	527120	279936	302531	160664	829651	440601
1977	605455	301672	343859	171330	949314	473001
1978	662533	304893	380556	175129	1043089	480022
1979	708932	301288	381242	162024	1090172	463312

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-3 USDA, SAES, AND COMBINED USDA AND SAES SCIENTIST YEARS, 1966-1979.

YEAR	USDA SCIENTIST YEARS	SAES SCIENTIST YEARS	COMB SCIENTIST YEARS
1966	3660.40	6146.00	9806.4
1967	3817.80	6179.00	9996.8
1968	3515.96	5752.50	9268.5
1969	3511.67	5955.90	9467.7
1970	3544.30	6031.10	9575.4
1971	3541.43	5841.10	9382.5
1972	3682.61	5914.30	9597.0
1973	3610.91	5953.50	9564.3
1974	3489.61	6034.20	9523.8
1975	3436.86	6133.40	9570.1
1976	3439.38	6281.30	9720.5
1977	3540.23	6556.70	10096.7
1978	3595.10	6514.02	10114.5
1979	3451.40	6520.47	9971.8

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-4 TOTAL RESEARCH EXPENDITURES BY USDA RESEARCH AGENCIES(ARS,ESS, AND CR)IN CURRENT AND CONSTANT DOLLARS 1966-1979.

YEAR	ARS RES EXP CURRENT $	ARS RES EXP CONSTANT $	CR RES EXP CURRENT $	CR RES EXP CONSTANT $	ESS RES EXP CURRENT $	ESS RES EXP CONSTANT $
1966	136761	143506	0.0	0.0	16323.0	17128.0
1967	145716	145716	1997.0	1997.0	17711.0	17711.0
1968	142405	134853	1969.9	1865.4	14774.9	13991.3
1969	146801	131660	1999.6	1793.4	15064.3	13510.6
1970	161113	133704	1694.4	1406.1	14089.1	11692.2
1971	176076	136387	2647.2	2050.5	18361.0	14222.3
1972	192617	139882	12500.0	9077.7	19190.8	13936.6
1973	200322	136088	15400.0	10462.0	20569.2	13973.6
1974	206995	126913	11583.0	7101.8	21604.9	13246.4
1975	224096	126251	16471.6	9279.8	25036.1	14104.9
1976	252514	134102	21973.8	11669.6	28043.0	14892.7
1977	292956	145967	21903.0	10913.3	28999.8	14449.3
1978	323146	148710	23707.0	10909.8	33703.0	15509.9
1979	327168	139043	16933.0	7196.3	37141.0	15784.5

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-5 TOTAL RESEARCH EXPENDITURES AT SAES BY SOURCE OF FUNDING (FEDERAL FORMULA FUNDS, COOPERATIVE GRANTS AND COOPERATIVE AGREEMENTS(CGCA), OTHER FEDERAL FUNDS, STATE APPROPRIATIONS, AND PRIVATE GRANTS) IN CURRENT AND CONSTANT DOLLARS 1966-1979.

($1000)

	FORMULA FUNDS		CGCA		OTHER FEDERAL	
YEAR	RES EXP CURRENT $	RES EXP CONSTANT $	RES EXP CURRENT $	RES EXP CONSTANT $	RES EXP CURRENT $	RES EXP CONSTANT $
1966	48017	50385.1	6008	6304.30	24522	25731.4
1967	48694	48694.0	6260	6260.00	23566	23566.0
1968	52449	49667.6	9594	9085.23	28602	27085.2
1969	53912	48351.6	7784	6981.17	27834	24963.2
1970	56439	46837.3	6837	5673.86	26440	21941.9
1971	62743	48600.3	6320	4895.43	25957	20106.1
1972	70587	51261.4	6850	4974.58	27299	19825.0
1973	77220	52459.2	7476	5078.80	28748	19529.9
1974	82127	50353.8	8631	5291.85	31205	19132.4
1975	90302	50874.4	10773	6069.30	34236	19287.9
1976	102505	54437.1	9882	5248.01	37772	20059.5
1977	116761	58176.9	11758	5858.50	51759	25789.2
1978	132179	60827.9	14783	6803.04	53590	24661.8
1979	142735	60660.9	17827	7576.29	56165	23869.5

	STATE APPROPRIATIONS		PRIVATE	
YEAR	RES EXP CURRENT $	RES EXP CONSTANT $	RES EXP CURRENT $	RES EXP CONSTANT $
1966	117942	123759	8726	9156.3
1967	120610	120610	8545	8545.0
1968	142276	134731	9766	9248.1
1969	157526	141279	12236	10974.0
1970	178666	148271	13719	11385.1
1971	190892	147864	14312	11086.0
1972	226185	164259	16021	11634.7
1973	247691	168268	17523	11904.2
1974	288022	176592	20624	12645.0
1975	331270	186631	23473	13224.2
1976	349502	185609	27459	14582.6
1977	393358	195993	31819	15854.0
1978	428489	197187	33587	15456.5
1979	457104	194264	35101	14917.6

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-6 PRIVATE INDUSTRY FUNDS FOR APPLIED RESEARCH AND DEVELOPMENT FOR AGRICULTURAL PRODUCTS, 1963-1975.

($MILLONS)

	FOOD AND KINDRED		FARM MACHINERY		AGRICULTURAL CHEMICALS		TOTAL PRIV AGR. RESEARCH	
YEAR	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1963	102	125.5	76	93.5	45	55.4	223	274.3
1964	118	139.0	79	93.1	48	56.5	245	288.6
1965	131	147.0	96	107.7	64	71.8	291	326.6
1966	130	137.9	100	106.0	77	81.7	307	325.6
1967	134	134.0	102	102.0	92	92.0	328	328.0
1968	165	154.3	96	89.8	99	92.6	360	336.0
1969	179	158.7	99	87.8	104	92.2	382	339.3
1970	204	170.1	89	74.2	126	105.1	419	349.5
1971	207	165.2	90	71.8	130	103.8	427	340.8
1972	222	168.9	92	70.0	108	82.2	422	321.2
1973	234	170.8	117	85.4	114	83.2	465	339.4
1974	269	181.8	127	85.8	137	92.6	533	360.1
1975	292	184.8	145	91.8	165	104.4	602	381.0

SOURCE: NSF, "TABLE B-51 RESEARCH AND DEVELOPMENT IN INDUSTRY 1975," SURVEYS OF SCIENCE RESOURCES SERIES, P. 72, NSF77-324.

TABLE A-7 PRIVATE RESEARCH AND DEVELOPMENT EXPENDITURE BY AGRICULTURAL INDUSTRIES ACCORDING TO CLASSIFICATION, 1975.

TYPE OF INDUSTRY	NO. OF COMPANIES	TOTAL R&D $1000
PLANT BREEDER	27	33683
PLANT FOOD	5	3366
ANIMAL FEED	28	27639
FEED INGREDIENT	9	13186
CHEMICAL	30	101138
ANIMAL HEALTH	19	92306
HUMAN FOOD	38	98554
MACHINERY	44	203836
BLDGS., EQPT., AND/OR SUPPLIES	4	1333
TOTALS	204	575044

SOURCE: WILCKE, H.L., AND WILLIAMSON. A SURVEY OF U.S. AGRICULTURAL RESEARCH BY PRIVATE INDUSTRY, WASHINGTON D.C.: AGRICULTURAL RESEACH INSTITUTE, 1977.

TABLE A-8 COMBINED SAES AND USDA RESEACH EXPENDITURES ON POST HARVEST TECHNOLOGY(PHT), PRODUCTION, OTHER, AND TOTAL IN CURRENT AND CONSTANT DOLLARS 1966-1979.

($1000)

	TOTAL RES EXP		PHT RES EXP		PRODUCTION RES EXP		OTHER RES EXP	
YEAR	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1966	358300	375970	87187	91487.3	237706	249429	33406	35053.6
1967	373100	373099	91991	91990.6	243012	243012	38096	38096.0
1968	401840	380527	94274	89274.2	267026	252866	40537	38387.4
1969	423160	379513	99183	88953.0	276815	248265	47159	42295.2
1970	459000	380911	104909	87061.4	304591	252772	49498	41077.1
1971	497310	385212	116753	90436.0	323257	250393	57298	44382.5
1972	571250	414851	133751	97132.2	367757	267072	69742	50647.4
1973	614950	417764	143791	97683.8	394389	267927	76769	52153.0
1974	670790	411276	154973	95017.1	429967	263622	85852	52637.5
1975	755120	425419	165978	93508.9	493299	277915	95842	53995.3
1976	830130	440854	180966	96105.4	542818	288273	106344	56476.0
1977	949820	473251	198220	98764.6	633814	315802	117781	58685.1
1978	1043090	480023	204858	94274.3	688376	316786	149855	68962.3
1979	1090170	463312	212093	90137.3	748487	318099	129594	55076.1

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-9 USDA RESEACH EXPENDITURES ON POST HARVEST TECHNOLOGY(PHT), PRODUCTION, OTHER, AND TOTAL IN CURRENT AND CONSTANT DOLLARS 1966-1979.

($1000)

	USDA TOTAL RES EXP		USDA PHT RES EXP		USDA PRODUCTION RES EXP		USDA OTHER RES EXP	
YEAR	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1966	153084	160634	54306	56984.7	87887	92221	10891.1	11428.2
1967	165424	165424	57783	57782.6	94945	94945	12696.0	12696.0
1968	159150	150710	56273	53288.4	91197	86361	11680.1	11060.7
1969	163865	146964	57634	51689.3	93691	84028	12540.2	11246.8
1970	176896	146802	62268	51674.6	100578	83467	14050.9	11660.5
1971	197084	152660	70642	54718.7	109052	84471	17389.8	13470.0
1972	224308	162896	79196	57513.5	124093	90119	21018.5	15264.0
1973	236291	160524	82339	55936.5	131078	89047	22874.2	15539.6
1974	240183	147261	86683	53147.1	132826	81439	20673.8	12675.5
1975	265604	149332	93786	52837.3	144936	81958	25803.6	14537.2
1976	302531	160918	100618	53435.2	173632	91957	29235.4	15526.0
1977	343859	171580	107751	53687.8	202076	100435	35036.9	17457.4
1978	380556	175129	109786	50522.8	229532	105629	41238.0	18977.5
1979	381242	162024	112272	47714.4	237289	100845	31681.0	13464.1

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-10 SAES RESEACH EXPENDITURES ON POST HARVEST TECHNOLOGY(PHT), PRODUCTION, OTHER, AND TOTAL IN CURRENT AND CONSTANT DOLLARS 1966-1979.

($1000)

	SAES TOTAL RES EXP		SAES PHT RES EXP		SAES PRODUCTION RES EXP		SAES OTHER RES EXP	
YEAR	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1966	205215	215336	32881	34502.6	149819	157208	22515	23625.4
1967	207675	207675	34208	34208.0	148067	148067	25400	25400.0
1968	242687	229817	38001	35985.8	175829	166505	28857	27326.7
1969	259292	232549	41549	37263.7	183124	164237	34619	31048.4
1970	282101	234109	42641	35386.7	204013	169305	35447	29416.6
1971	300224	232552	46111	35717.3	214205	165922	39908	30912.5
1972	346942	251955	54555	39618.7	243664	176953	48723	35383.4
1973	378658	257240	61452	41747.3	263311	178880	53895	36613.5
1974	430609	264015	68290	41870.0	297141	182183	65178	39962.0
1975	490054	276087	72192	40671.5	347824	195957	70038	39458.0
1976	527120	279936	80348	42670.2	369663	196316	77109	40950.1
1977	605455	301672	90469	45076.7	432242	215367	82744	41227.7
1978	662533	304893	95072	43751.5	458844	211157	108617	49984.8
1979	708932	301289	99821	42422.9	511198	217254	97913	41612.0

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-11 POTATO POST HARVEST TECHNOLOGY(PHT), NON-PHT, AND TOTAL RESEARCH BY SAES AND USDA IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

	SAES	PHT	SAES	TOTAL	USDA	PHT	USDA	TOTAL
YEAR	CUR	CON	CUR	CON	CUR	CON	CUR	CON
	$	$	$	$	$	$	$	$
1966	488.31	512.392	2758	2894.02	879.66	923.05	1838	1928.65
1967	575.00	575.000	2924	2924.00	1022.00	1022.00	2007	2007.00
1968	652.92	618.294	2630	2490.53	1068.18	1011.53	1839	1741.48
1969	833.04	747.119	3053	2738.12	1333.22	1195.71	2103	1886.10
1970	935.48	776.335	3466	2876.35	1149.21	953.71	2177	1806.64
1971	1027.01	795.512	3808	2949.65	1342.02	1039.52	2332	1806.35
1972	980.17	711.816	3941	2862.02	1481.92	1076.19	2617	1900.51
1973	1068.95	726.188	4334	2944.29	1692.97	1150.12	2777	1886.55
1974	1092.19	669.643	4862	2980.99	1927.49	1181.78	2999	1838.75
1975	1358.93	765.592	5398	3041.13	1942.89	1094.58	3222	1815.21
1976	1554.09	825.328	6319	3355.82	1966.54	1044.36	3497	1857.14
1977	1609.51	801.949	7197	3585.95	2288.49	1140.26	4222	2103.64
1978	1477.33	679.858	8001	3682.01	2286.16	1052.08	3903	1796.13
1979	1289.89	548.188	8646	3674.46	2145.71	911.90	3897	1656.18

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. I, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-12 OTHER VEGETABLES POST HARVEST TECHNOLOGY(PHT), NON-PHT, AND TOTAL RESEARCH BY SAES AND USDA IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

YEAR	SAES PHT CUR $	SAES PHT CON $	SAES TOTAL CUR $	SAES TOTAL CON $	USDA PHT CUR $	USDA PHT CON $	USDA TOTAL CUR $	USDA TOTAL CON $
1966	1839.22	1929.92	13660	14333.7	2000.78	2099.46	5911	6202.52
1967	1863.00	1863.00	14401	14401.0	2143.00	2143.00	6072	6072.00
1968	2512.61	2379.37	13933	13194.1	2196.06	2079.60	5561	5266.10
1969	2874.77	2578.27	14815	13287.0	2393.38	2146.52	6014	5393.72
1970	2429.56	2016.24	15590	12937.8	2548.89	2115.26	6531	5419.92
1971	2514.63	1947.82	16669	12911.7	2848.41	2206.36	7388	5722.70
1972	2563.58	1861.72	17317	12575.9	3474.03	2522.90	8492	6167.03
1973	2727.76	1853.10	19067	12953.1	3622.99	2461.27	9090	6175.27
1974	3357.12	2058.32	23125	14178.4	3776.69	2315.56	9503	5826.49
1975	3667.73	2066.33	26295	14814.1	4189.95	2360.54	9925	5591.55
1976	4555.15	2419.09	30818	16366.4	4597.14	2441.39	11116	5903.35
1977	4958.69	2470.70	33530	16706.5	4941.53	2462.15	12280	6118.58
1978	5314.38	2445.64	37092	17069.5	5492.57	2527.64	12196	5612.52
1979	5540.36	2354.60	39956	16980.9	5335.63	2267.59	12906	5484.91

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. I, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-13 SORGHUM POST HARVEST TECHNOLOGY(PHT), NON-PHT, AND TOTAL RESEARCH BY SAES AND USDA IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

	SAES PHT		SAES TOTAL		USDA PHT		USDA TOTAL	
YEAR	CUR $	CON $	CUR $	CON $	CUR $	CON $	CUR $	CON $
1966	143.227	150.291	1262	1324.24	419.73	440.430	913	958.03
1967	127.000	127.000	1288	1288.00	480.00	480.000	1087	1087.00
1968	60.562	57.350	1235	1169.51	617.68	584.927	1025	970.64
1969	82.287	73.800	1403	1258.30	1002.82	899.387	1408	1262.78
1970	116.959	97.061	1846	1531.95	872.75	724.271	1345	1116.18
1971	109.101	84.509	2119	1641.36	863.86	669.143	1333	1032.53
1972	106.772	77.540	2160	1568.63	925.40	672.044	1484	1077.71
1973	149.544	101.592	2526	1716.03	797.87	542.030	1413	959.92
1974	252.606	154.878	3147	1929.49	852.67	522.791	1672	1025.14
1975	382.589	215.543	3484	1962.82	964.99	543.659	1667	939.15
1976	444.757	236.196	4021	2135.42	1029.24	546.596	1832	972.92
1977	496.784	247.526	4396	2190.33	1250.67	623.154	2245	1118.58
1978	419.142	192.886	4704	2164.75	1089.72	501.482	1707	785.55
1979	435.235	184.970	4761	2023.37	1043.76	443.585	1845	784.11

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. I, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-14 CORN POST HARVEST TECHNOLOGY(PHT), NON-PHT, AND TOTAL RESEARCH BY SAES AND USDA IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

YEAR	SAES PHT CUR $	SAES PHT CON $	SAES TOTAL CUR $	SAES TOTAL CON $	USDA PHT CUR $	USDA PHT CON $	USDA TOTAL CUR $	USDA TOTAL CON $
1966	531.81	558.04	5783	6068.21	3329.57	3493.78	6164	6468.00
1967	531.00	531.00	5690	5690.00	3415.00	3415.00	6100	6100.00
1968	664.17	628.95	6332	5996.23	3054.00	2892.05	5433	5144.89
1969	735.86	659.96	6975	6255.61	3044.01	2730.06	5457	4894.17
1970	556.90	462.16	7153	5936.10	3599.65	2987.26	6106	5067.22
1971	1013.58	785.11	8477	6566.23	3929.55	3043.80	7911	6127.81
1972	1164.94	846.00	9455	6866.38	4161.74	3022.32	8166	5930.28
1973	1349.87	917.03	10424	7081.52	4036.08	2741.90	7645	5193.61
1974	1368.76	839.22	11492	7045.98	3973.07	2435.97	7888	4836.30
1975	1449.79	816.78	13071	7363.94	4568.33	2573.71	8590	4839.44
1976	1456.68	773.60	14794	7856.61	4370.47	2321.02	9187	4878.92
1977	1545.52	770.07	15576	7760.84	4679.42	2331.55	9608	4787.24
1978	2246.82	1033.97	18410	8472.16	4936.44	2271.72	9988	4596.41
1979	2310.51	981.94	20002	8500.64	5322.45	2261.98	11263	4786.66

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. I, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-15 WHEAT POST HARVEST TECHNOLOGY(PHT), NON-PHT, AND TOTAL RESEARCH BY SAES AND USDA IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

	SAES	PHT	SAES	TOTAL	USDA	PHT	USDA	TOTAL
YEAR	CUR $	CON $	CUR $	CON $	CUR $	CON $	CUR $	CON $
1966	774.05	812.220	3928	4121.72	3344.25	3509.18	7077	7426.02
1967	731.00	731.000	3826	3826.00	3825.00	3825.00	7376	7376.00
1968	862.00	816.290	3999	3786.93	4114.61	3896.41	6313	5978.22
1969	869.53	779.847	4547	4078.03	3797.26	3405.61	6083	5455.61
1970	868.04	720.368	5266	4370.12	4385.19	3639.16	6777	5624.07
1971	711.98	551.498	5526	4280.40	4492.20	3479.63	7077	5481.80
1972	892.48	648.131	5889	4276.69	4529.77	3289.60	7645	5551.92
1973	1213.17	824.166	6524	4432.07	4451.44	3024.07	7584	5152.17
1974	1144.76	701.877	6904	4232.99	4491.41	2753.78	7945	4871.24
1975	1407.75	793.098	8186	4611.83	4825.18	2718.41	8434	4751.55
1976	1650.33	876.435	9925	5270.84	4882.88	2593.14	9099	4832.18
1977	1734.20	864.077	11600	5779.77	5399.98	2690.57	10105	5034.88
1978	1871.17	861.098	12716	5851.82	4482.86	2062.98	8872	4082.83
1979	1987.14	844.512	13764	5849.55	4309.80	1831.62	9012	3830.00

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. I, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-16 SOYBEAN POST HARVEST TECHNOLOGY(PHT), NON-PHT, AND TOTAL RESEARCH BY SAES AND USDA IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

	SAES PHT		SAES TOTAL		USDA PHT		USDA TOTAL	
YEAR	CUR $	CON $	CUR $	CON $	CUR $	CON $	CUR $	CON $
1966	154.84	162.480	2340	2455.40	1346.39	1412.80	2986	3133.26
1967	171.00	171.000	2572	2572.00	1258.00	1258.00	3227	3227.00
1968	334.86	317.101	3217	3046.40	1478.44	1400.04	3366	3187.50
1969	671.80	602.511	4200	3766.82	1682.13	1508.63	3636	3260.99
1970	408.29	338.833	4976	4129.46	1524.42	1265.08	3379	2804.15
1971	487.51	377.624	5491	4253.29	1922.35	1489.04	4373	3387.30
1972	434.56	315.585	6309	4581.70	1950.13	1416.22	5144	3735.66
1973	501.68	340.818	7118	4835.60	1986.75	1349.70	5786	3930.71
1974	600.67	368.283	8570	5254.45	2155.65	1321.67	6579	4033.72
1975	908.49	511.827	11312	6372.96	2464.45	1388.42	7331	4130.14
1976	1246.23	661.831	14515	7708.44	2977.52	1581.26	9329	4954.33
1977	1655.28	824.753	17912	8924.76	3501.50	1744.65	10877	5419.53
1978	1826.96	840.753	21550	9917.17	3938.86	1812.64	10534	4847.68
1979	2104.80	894.517	23447	9964.73	3928.63	1669.63	11587	4924.35

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. I, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-17 RICE POST HARVEST TECHNOLOGY(PHT), NON-PHT, AND TOTAL RESEARCH BY SAES AND USDA IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

YEAR	SAES PHT		SAES TOTAL		USDA PHT		USDA TOTAL	
	CUR $	CON $	CUR $	CON $	CUR $	CON $	CUR $	CON $
1966	89.870	94.302	673	706.19	419.49	440.180	823	863.59
1967	86.000	86.000	728	728.00	462.00	462.000	838	838.00
1968	86.114	81.547	987	934.66	621.17	588.228	956	905.30
1969	120.125	107.735	1067	956.95	629.03	564.151	1019	913.90
1970	77.222	64.085	1138	944.40	645.95	536.058	1049	870.54
1971	128.147	99.262	1407	1089.85	709.60	549.649	1187	919.44
1972	153.495	111.471	1363	989.83	821.49	596.578	1341	973.86
1973	141.708	96.269	1660	1127.72	770.84	523.669	1336	907.61
1974	212.304	130.168	2374	1455.55	772.99	473.937	1233	755.98
1975	235.460	132.654	2881	1623.10	905.31	510.032	1410	794.37
1976	332.718	176.696	3114	1653.74	1167.02	619.768	1794	952.73
1977	367.408	183.063	3069	1529.15	1466.46	730.675	2205	1098.65
1978	374.479	172.333	3469	1596.41	1423.06	654.885	1962	902.90
1979	361.623	153.686	3796	1613.26	1209.59	514.062	1686	716.53

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. I, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-18 SMALL GRAINS POST HARVEST TECHNOLOGY(PHT), NON-PHT, AND TOTAL RESEARCH BY SAES AND USDA IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

	SAES PHT		SAES TOTAL		USDA PHT		USDA TOTAL	
YEAR	CUR $	CON $	CUR $	CON $	CUR $	CON $	CUR $	CON $
1966	269.00	282.271	3199	3356.77	81.64	85.667	1386	1454.35
1967	236.00	236.000	3070	3070.00	135.00	135.000	1414	1414.00
1968	195.64	185.261	3348	3170.45	172.46	163.311	1553	1470.64
1969	192.96	173.057	3444	3088.79	251.46	225.526	1579	1416.14
1970	189.28	157.077	3287	2727.80	141.38	117.324	1508	1251.45
1971	154.24	119.475	3412	2642.91	266.44	206.381	1803	1396.59
1972	158.29	114.951	3710	2694.26	616.18	447.483	2699	1960.06
1973	255.73	173.727	4442	3017.66	546.60	371.333	2920	1983.70
1974	315.94	193.711	4892	2999.39	541.36	331.917	3436	2106.68
1975	375.42	211.504	5012	2823.66	831.46	468.429	3233	1821.41
1976	433.89	230.426	6497	3450.35	1149.21	610.311	7581	4026.02
1977	512.88	255.546	7351	3662.68	882.06	439.492	4073	2029.40
1978	545.06	250.831	7648	3519.56	673.00	309.710	2689	1237.46
1979	1205.50	512.325	8749	3718.23	960.83	408.342	2768	1176.37

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. I, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-19 COTTON POST HARVEST TECHNOLOGY(PHT), NON-PHT, AND TOTAL RESEARCH BY SAES AND USDA IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

	SAES	PHT	SAES	TOTAL	USDA	PHT	USDA	TOTAL
YEAR	CUR	CON	CUR	CON	CUR	CON	CUR	CON
	$	$	$	$	$	$	$	$
1966	336.579	353.178	6895	7235.05	5251.70	5510.71	12102	12698.8
1967	373.000	373.000	7414	7414.00	5485.00	5485.00	13062	13062.0
1968	348.673	330.183	6406	6066.29	6221.47	5891.55	14427	13661.9
1969	372.667	334.230	7137	6400.90	5830.19	5228.87	14780	13255.6
1970	381.399	316.514	7745	6427.39	7037.28	5840.07	15825	13132.8
1971	353.025	273.451	7899	6118.51	6580.62	5097.30	17184	13310.6
1972	389.099	282.570	8701	6318.81	7210.38	5236.30	20377	14798.1
1973	480.704	326.565	10407	7069.97	6938.32	4713.53	20658	14034.0
1974	431.623	264.637	10753	6592.89	7270.38	4457.62	19357	11868.2
1975	393.205	221.524	12211	6879.44	7200.41	4056.57	20193	11376.3
1976	448.508	238.188	11115	5902.81	6364.54	3380.00	22014	11690.9
1977	476.800	237.569	13174	6564.03	5491.17	2736.01	23099	11509.2
1978	440.128	202.544	12071	5554.99	6276.02	2888.18	23584	10853.2
1979	411.384	174.834	12788	5434.76	5932.01	2521.04	22718	9654.9

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. I, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-20 COTTON SEED POST HARVEST TECHNOLOGY(PHT), NON-PHT, AND TOTAL RESEARCH BY SAES AND USDA IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

	SAES PHT		SAES TOTAL		USDA PHT		USDA TOTAL	
YEAR	CUR $	CON $	CUR $	CON $	CUR $	CON $	CUR $	CON $
1966	239.913	251.745	365	383.001	1011.23	1061.10	1588	1666.32
1967	166.000	166.000	327	327.000	1105.00	1105.00	1545	1545.00
1968	163.131	154.480	204	193.182	1178.00	1115.53	1383	1309.66
1969	156.521	140.378	200	179.372	1415.83	1269.80	1595	1430.49
1970	115.273	95.662	165	136.929	1789.89	1485.39	1919	1592.53
1971	97.204	75.294	142	109.992	1827.04	1415.21	2108	1632.84
1972	78.018	56.658	153	111.111	1854.60	1346.84	2136	1551.20
1973	89.106	60.534	137	93.071	2320.92	1576.71	2639	1792.80
1974	103.000	63.151	103	63.151	2074.32	1271.81	2379	1458.61
1975	140.389	79.092	185	104.225	2201.61	1240.34	2473	1393.24
1976	114.754	60.942	154	81.784	1845.86	980.28	2139	1135.95
1977	209.957	104.612	246	122.571	2014.22	1003.60	2297	1144.49
1978	231.251	106.420	265	121.951	2134.43	982.25	2425	1115.97
1979	301.254	128.030	342	145.346	2122.51	902.05	2398	1019.12

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. I, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-21 DAIRY POST HARVEST TECHNOLOGY(PHT), NON-PHT, AND TOTAL RESEARCH BY SAES AND USDA IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

YEAR	SAES PHT CUR $	SAES PHT CON $	SAES TOTAL CUR $	SAES TOTAL CON $	USDA PHT CUR $	USDA PHT CON $	USDA TOTAL CUR $	USDA TOTAL CON $
1966	3486.93	3658.90	19324	20277.0	2351.93	2467.92	9869	10355.7
1967	3503.00	3503.00	18607	18607.0	2471.00	2471.00	10162	10162.0
1968	4029.54	3815.85	18463	17483.9	3493.19	3307.95	10048	9515.2
1969	4160.06	3730.99	19541	17525.6	3440.33	3085.50	10022	8988.3
1970	4490.85	3726.85	20686	17166.8	3972.53	3296.71	11014	9140.2
1971	4328.20	3352.59	21190	16413.6	4386.39	3397.67	12295	9523.6
1972	4291.75	3116.74	21824	15848.9	5075.03	3685.57	13640	9905.6
1973	3913.56	2658.67	23566	16009.5	4735.28	3216.90	13176	8951.1
1974	4631.67	2839.77	27074	16599.6	3868.58	2371.91	12794	7844.3
1975	5775.29	3253.69	29748	16759.4	3929.10	2213.58	14245	8025.4
1976	6378.11	3387.21	34068	18092.4	3868.90	2054.65	14726	7820.5
1977	7323.45	3648.95	37362	18615.8	3808.18	1897.45	17567	8752.9
1978	7737.63	3560.81	39708	18273.4	2977.60	1370.27	15102	6949.8
1979	7789.62	3310.50	44052	18721.6	3276.33	1392.41	17763	7549.1

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. I, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-22 BEEF POST HARVEST TECHNOLOGY(PHT), NON-PHT, AND TOTAL RESEARCH BY SAES AND USDA IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

YEAR	SAES PHT		SAES TOTAL		USDA PHT		USDA TOTAL	
	CUR $	CON $	CUR $	CON $	CUR $	CON $	CUR $	CON $
1966	1437.50	1508.40	18677	19598.1	2408.36	2527.14	10445	10960.1
1967	1484.00	1484.00	17729	17729.0	2491.00	2491.00	10882	10882.0
1968	2215.89	2098.38	19050	18039.8	3330.42	3153.81	10316	9768.9
1969	2094.21	1878.21	20121	18045.7	3427.13	3073.66	10460	9381.2
1970	1902.10	1578.51	22637	18785.9	3387.65	2811.33	11338	9409.1
1971	1882.98	1458.54	23385	18113.9	3888.13	3011.72	13078	10130.1
1972	2305.82	1674.53	25739	18692.1	4061.54	2949.56	14416	10469.1
1973	2401.67	1631.57	28872	19614.1	4739.11	3219.50	15163	10301.0
1974	2917.97	1789.07	34978	21445.7	4891.86	2999.30	15922	9762.1
1975	3247.19	1829.40	37596	21180.8	5971.14	3364.02	18751	10563.9
1976	4265.46	2265.25	44178	23461.5	6306.79	3349.33	23212	12327.1
1977	4347.60	2166.22	55179	27493.3	5751.31	2865.63	24131	12023.4
1978	4503.50	2072.48	57556	26486.9	9162.60	4216.57	27906	12842.2
1979	4829.54	2052.50	62194	26431.8	5065.52	2152.79	24180	10276.2

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. I, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-23 RESEARCH EXPENDITURES PER SCIENTIST YEAR AT SAES, USDA, AND COMBINED SAES AND USDA IN CONSTANT AND CURRENT DOLLARS 1966-1979.

(DOLLARS)

	SAES RES EXP PER SCIENTIST YR		USDA RES EXP PER SCIENTIST YR		COMBINED RES EXP PER SCIENTIST YR	
YEAR	CURRENT $	CONSTANT $	CURRENT $	CONSTANT $	CURRENT $	CONSTANT $
1966	33390.0	35036.7	69793	73235.1	42965	45083.5
1967	33609.8	33609.8	69259	69258.5	43548	43548.2
1968	42188.1	39950.9	45265	42864.1	43355	41056.0
1969	43535.3	39045.1	46663	41849.9	44695	40085.4
1970	46774.4	38816.9	49910	41419.1	47935	39780.1
1971	51398.5	39812.9	55651	43107.2	53004	41056.4
1972	58661.5	42600.9	60910	44234.0	59524	43227.6
1973	63602.6	43208.3	65438	44455.3	64296	43679.1
1974	71361.4	43753.2	68828	42200.0	70433	43184.1
1975	79899.2	45013.6	77281	43538.4	78960	44484.5
1976	83918.9	44566.6	87961	46713.2	85351	45326.9
1977	92341.4	46009.7	97129	48395.0	94022	46846.8
1978	101708.7	46805.6	105854	48713.3	103128	47458.8
1979	107259.9	45584.3	110460	46944.4	127100	46048.4

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-24 POST HARVEST TECHNOLOGY(PHT) RESEARCH EXPENDITURES PER SCIENTIST YEAR AT SAES, USDA, AND COMBINED SAES AND USDA IN CONSTANT AND CURRENT DOLLARS 1966-1979.

(DOLLARS)

YEAR	SAES PHT RES EXP PER SCIENTIST YR		USDA PHT RES EXP PER SCIENTIST YR		COMBINED PHT RES EXP PER SCIENTIST YR	
	CURRENT $	CONSTANT $	CURRENT $	CONSTANT $	CURRENT $	CONSTANT $
1966	30891.6	32415.1	35556.9	37310.5	33628.7	35287.2
1967	32192.7	32192.7	36081.5	36081.5	34520.7	34520.7
1968	39975.8	37855.9	39431.2	37340.2	39650.2	37547.5
1969	42509.7	38125.3	40058.4	35926.8	41056.0	36821.5
1970	43878.4	36413.6	42864.9	35572.5	43273.4	35911.5
1971	47161.4	36530.9	47954.3	37145.1	47636.4	36898.8
1972	53945.4	39176.0	51031.5	37059.9	52187.2	37899.2
1973	57935.3	39358.2	54385.9	36946.9	55852.2	37943.1
1974	62876.3	38550.8	58286.5	35736.7	60228.0	36927.0
1975	64042.9	36080.5	64379.2	36270.0	64235.2	36188.8
1976	74596.6	39615.8	72013.2	38243.9	73138.8	38841.6
1977	79898.4	39809.9	77141.7	38436.3	78375.9	39051.3
1978	84561.1	38914.5	78891.9	36305.5	81425.3	37471.4
1979	89125.9	37877.5	85940.0	36523.6	84331.2	35839.8

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-25 RESEARCH EXPENDITURES IN SAES, USDA, AND COMBINED SAES AND USDA PER $1000 OF AGRICULTURAL OUTPUT, 1966-1979.

(DOLLARS)

YEAR	SAES RES PER $1000 AG PROD. $	USDA RES PER $1000 AG PROD. $	COMB RES PER $1000 AG PROD. $
1966	4.09922	3.05789	7.15711
1967	4.14927	3.30511	7.45438
1968	4.72641	3.09950	7.82591
1969	4.64041	2.93260	7.57301
1970	4.85820	3.04641	7.90461
1971	4.89116	3.21083	8.10199
1972	4.94536	3.19732	8.14268
1973	3.77985	2.35871	6.13856
1974	4.42326	2.46719	6.89045
1975	4.94480	2.67459	7.61938
1976	5.24732	3.01636	8.26368
1977	5.65983	3.21910	8.87893
1978	5.33118	3.06221	8.39339
1979	4.78685	2.57422	7.36107

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-26 PHT RESEARCH EXPENDITURES AT SAES, USDA, AND COMBINED SAES AND PER $1000 OF AGRICULTURAL OUTPUT, 1966-1979.

(DOLLARS)

YEAR	SAES PHT RES PER $1000 AG PROD. $	USDA PHT RES PER $1000 AG PROD. $	COMB PHT RES PER $1000 AG PROD. $
1966	0.656806	1.08477	1.74158
1967	0.683463	1.15448	1.83795
1968	0.740082	1.09594	1.83602
1969	0.743580	1.03144	1.77502
1970	0.734341	1.07235	1.80669
1971	0.751226	1.15088	1.90210
1972	0.777635	1.12887	1.90651
1973	0.613428	0.82193	1.43536
1974	0.701482	0.89042	1.59190
1975	0.728440	0.94633	1.67477
1976	0.799841	1.00162	1.80146
1977	0.845710	1.00726	1.85297
1978	0.765013	0.88341	1.64842
1979	0.674011	0.75808	1.43209

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-27 ALL RESEARCH AND PHT RESEARCH AT SAES AS A PERCENT OF TOTAL AGRICULTURAL RESEARCH EXPENDITURES IN CONSTANT AND CURRENT DOLLARS, 1966-1979.

(PERCENTAGE)

YEAR	SAES PERCENT TOTAL RES	SAES PERCENT PHT RES
1966	0.572748	0.377132
1967	0.556622	0.371862
1968	0.603944	0.403091
1969	0.612756	0.418913
1970	0.614603	0.406457
1971	0.603698	0.394945
1972	0.607338	0.407885
1973	0.615755	0.427370
1974	0.641941	0.440657
1975	0.648976	0.434949
1976	0.634986	0.443995
1977	0.637445	0.456407
1978	0.635164	0.464087
1979	0.650293	0.470647

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-28 RESEARCH AND DEVELOPMENT EXPENDITURES BY GOVERNMENT AGENCIES (DOD, HEW, USDA, DOE, NASA, NSF, OTHER SELECTED AGENCIES AND TOTAL) AT SAES AND USDA IN CURRENT AND CONSTANT DOLLARS 1966-1978.

($1000)

YEAR	DOE R+D EXPENDITURE CUR $	DOE R+D EXPENDITURE CONST $	NASA R+D EXPENDITURE CUR $	NASA R+D EXPENDITURE CONST $	NSF R+D EXPENDITURE CUR $	NSF R+D EXPENDITURE CONST $	OTHER R+D EXPENDITURE CUR $	OTHER R+D EXPENDITURE CONST $
1966	1212	1271.77	5050	5299.06	244	256.034	541	567.68
1967	1257	1257.00	4867	4867.00	262	262.000	694	694.00
1968	1369	1296.40	4429	4194.13	284	268.939	625	591.86
1969	1406	1260.99	3963	3554.26	274	245.740	744	667.26
1970	1346	1117.01	3800	3153.53	289	239.834	1043	865.56
1971	1303	1009.30	3258	2523.63	337	261.038	1357	1051.12
1972	1298	942.63	3157	2292.67	455	330.428	1169	848.95
1973	1363	925.95	3061	2079.48	480	326.087	1288	875.00
1974	1489	912.94	3002	1840.59	556	340.895	1278	783.57
1975	2047	1153.24	3064	1726.20	595	335.211	1486	837.18
1976	2464	1308.55	3447	1830.59	609	323.420	1541	818.37
1977	3536	1761.83	3703	1845.04	697	347.285	1695	844.54
1978	4196	1930.97	3876	1783.71	754	346.986	2005	922.69

YEAR	DOD R+D EXPENDITURE CUR $	DOD R+D EXPENDITURE CONST $	HEW R+D EXPENDITURE CUR $	HEW R+D EXPENDITURE CONST $	USDA R+D EXPENDITURE CUR $	USDA R+D EXPENDITURE CONST $	TOTAL R+D EXPENDITURE CUR $	TOTAL R+D EXPENDITURE CONST $
1966	7024	7370.41	1014	1064.01	153	160.546	15247	15999.0
1967	8049	8049.00	1147	1147.00	165	165.000	16441	16441.0
1968	7709	7300.19	1252	1185.61	159	150.568	15827	14987.7
1969	7696	6902.24	1297	1163.23	163	146.188	15543	13939.9
1970	7360	6107.88	1221	1013.28	177	146.888	15236	12644.0
1971	7509	5816.42	1476	1143.30	197	152.595	15437	11957.4
1972	8318	6040.67	1751	1271.60	224	162.672	16377	11893.2
1973	8404	5709.24	1838	1248.64	236	160.326	16670	11324.7
1974	8420	5162.48	2290	1404.05	240	147.149	17275	10591.7
1975	9012	5077.18	2363	1331.27	265	149.296	18832	10609.6
1976	9655	5127.46	2546	1352.10	303	160.913	20565	10921.4
1977	10963	5462.38	2787	1388.64	344	171.400	23725	11821.1
1978	11825	5441.79	3132	1441.33	381	175.334	26169	12042.8

SOURCE: NSF, SCIENCE INDICATORS 1979, "TABLE 4-2 RESEARCH AND DEVELOPMENT EXPENDITURES BY U.S. GOVERNMENT DEPARTMENTS, 1966-1978."

TABLE A-29 R+D EXPENDITURES PER SCIENTIST YEAR BY PRIVATE INDUSTRY, FOOD AND KINDRED PRODUCTS INDUSTRY, AND THE CHEMICAL INDUSTRY IN CONSTANT AND CURRENT DOLLARS, 1963-1978.

(DOLLARS)

YEAR	TOTAL PRIV R+D EXPEND/SCIEN.YR CUR $	TOTAL PRIV R+D EXPEND/SCIEN.YR CONST $	PRIV FOOD R+D EXPEND/SCIEN.YR CUR $	PRIV FOOD R+D EXPEND/SCIEN.YR CONST $	PRIV CHEM R+D EXPEND/SCIEN.YR CUR $	PRIV CHEM R+D EXPEND/SCIEN.YR CONST $
1963	37800	43851.5	25200	29234.3	32600	37819.0
1964	39500	44835.4	24200	27468.8	34800	39500.6
1965	40700	44774.5	25300	27832.8	35700	39273.9
1966	43200	45330.5	26700	28016.8	37600	39454.4
1967	44100	44100.0	29500	29500.0	39800	39800.0
1968	45600	43181.8	29700	28125.0	40100	37973.5
1969	47500	42600.9	32500	29148.0	41200	36950.7
1970	48100	39917.0	36200	30041.5	42600	35352.7
1971	51100	39581.7	36800	28505.0	43500	33694.8
1972	54900	39869.3	38800	28177.2	46500	33769.1
1973	58200	39538.0	39900	27106.0	49200	33423.9
1974	62300	38197.4	43400	26609.4	55000	33721.6
1975	66500	37464.8	48900	27549.3	60900	34309.9
1976	72200	38343.1	51400	27296.9	66500	35316.0
1977	76100	37917.3	57200	28500.2	69100	34429.5
1978	79500	36585.4	59800	27519.6	74000	34054.3

SOURCE: NSF, "TABLE B-30 COST PER R+D SCIENTIST OR ENGINEER BY INDUSTRY: 1963-1978, RESEARCH AND DEVELOPMENT IN INDUSTRY 1978 P.54., NSF 80-324.

TABLE A-30 AGRICULTURAL RESEARCH SERVICE(ARS) EXPENDITURE ON TOTAL, POST HARVEST TECHNOLOGY(PHT), PRODUCTION, AND OTHER RESEARCH IN CURRENT AND CONSTANT DOLLARS 1966-1979.

($1000)

		ARS TOTAL RES EXP		ARS PHT RES EXP		ARS PROD RES EXP		ARS OTHER RES EXP	
	YEAR	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1	1966	136761	143506	46211.4	48490.5	85214	89416.4	5335.8	5599.0
2	1967	145716	145716	49356.0	49356.0	90055	90055.0	6305.0	6305.0
3	1968	142405	134853	46331.0	43874.1	88642	83941.3	7432.0	7037.9
4	1969	146801	131660	47570.0	42663.7	91181	81776.7	8050.0	7219.7
5	1970	161113	133704	53560.0	44448.1	98828	82014.9	8725.0	7240.7
6	1971	176076	136387	59240.0	45886.9	106396	82413.6	10440.0	8086.8
7	1972	192617	139882	63315.2	45980.5	117850	85584.4	11452.1	8316.7
8	1973	200322	136088	66309.7	45047.4	122354	83121.1	11658.0	7919.8
9	1974	206995	126913	69009.7	42311.3	124831	76536.4	13154.4	8065.2
10	1975	224096	126251	72334.9	40752.1	137235	77315.4	14526.2	8183.8
11	1976	252514	134102	76733.6	40750.7	159503	84706.6	16277.8	8644.6
12	1977	292956	145967	84070.4	41888.6	188927	94133.9	19958.9	9944.6
13	1978	323146	148710	82577.0	38001.4	213061	98049.2	27508.0	12659.0
14	1979	327168	139043	86336.0	36691.9	223186	94851.7	17646.0	7499.4

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-31 ECONOMIC STATISTICS SERVICE(ESS) EXPENDITURE ON TOTAL, POST HARVEST TECHNOLOGY(PHT), PRODUCTION, AND OTHER RESEARCH IN CURRENT AND CONSTANT DOLLARS 1966-1979.

($1000)

	ESS TOTAL RES EXP		ESS PHT RES EXP		ESS PROD RES EXP		ESS OTHER RES EXP	
YEAR	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1966	16323.0	17128.0	8095.0	8494.24	2672.70	2804.51	5555.3	5829.28
1967	17711.0	17711.0	8426.6	8426.59	2893.40	2893.40	6391.0	6391.00
1968	14774.9	13991.3	9832.1	9310.68	864.53	818.68	4078.3	3862.00
1969	15064.3	13510.6	9949.5	8923.33	736.53	660.57	4378.3	3926.70
1970	14089.1	11692.2	8566.7	7109.27	335.80	278.67	5186.6	4304.23
1971	18361.0	14222.3	11226.9	8696.25	324.00	250.97	6810.1	5275.06
1972	19190.8	13936.7	12212.8	8869.13	360.60	261.87	6617.4	4805.66
1973	20569.1	13973.6	12354.3	8392.84	972.90	660.94	7241.9	4919.77
1974	21604.9	13246.4	13366.2	8195.12	3086.60	1892.46	5152.1	3158.86
1975	24497.1	13801.2	15757.4	8877.39	1534.50	864.51	7205.2	4059.27
1976	28520.3	15146.2	17096.6	9079.43	2222.60	1180.35	9201.1	4886.40
1977	29501.3	14699.2	17051.0	8495.77	2473.60	1232.49	9976.7	4970.95
1978	33703.0	15509.9	20296.0	9340.08	4661.00	2144.96	8746.0	4024.85
1979	37141.0	15784.5	22392.0	9516.36	2756.00	1171.27	11993.0	5096.90

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-32 COOPERATIVE STATE RESEARCH SERVICE(CSRS) EXPENDITURE ON TOTAL, POST HARVEST TECHNOLOGY(PHT), PRODUCTION, AND OTHER RESEARCH IN CURRENT AND CONSTANT DOLLARS 1966-1979, U.S.

($1000)

	CSRS TOTAL RES EXP		CSRS PHT RES EXP		CSRS PROD RES EXP		CSRS OTHER RES EXP	
YEAR	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1966	0.0	0.0	0.00	0.00	0.0	0.00	0.00	0.00
1967	1997.0	1997.0	0.00	0.00	1997.0	1997.00	0.00	0.00
1968	1969.9	1865.4	109.43	103.63	1690.6	1600.95	169.87	160.86
1969	1999.6	1793.4	114.10	102.33	1773.6	1590.66	111.91	100.37
1970	1694.4	1406.1	141.26	117.23	1413.9	1173.34	139.27	115.58
1971	2647.2	2050.5	175.00	135.55	2332.5	1806.75	139.69	108.20
1972	12500.0	9077.7	3668.07	2663.81	5882.9	4272.26	2949.03	2141.63
1973	15400.0	10462.0	3674.61	2496.34	7751.0	5265.65	3974.35	2699.97
1974	11583.0	7101.8	4306.90	2640.65	4908.8	3009.69	2367.29	1451.43
1975	16471.6	9279.8	5694.02	3207.90	6705.4	3777.68	4072.20	2294.20
1976	21973.8	11669.6	6788.25	3605.02	11429.1	6069.60	3756.49	1994.95
1977	21903.0	10913.3	6630.09	3303.48	10171.6	5068.06	5101.31	2541.76
1978	23707.0	10909.8	6913.00	3181.32	11810.0	5434.88	4984.00	2293.60
1979	16933.0	7196.3	3544.00	1506.16	11347.0	4822.35	2042.00	867.83

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-33 FEDERAL EXPEDITURE FOR R+D IN THE FOOD AND KINDRED PRODUCTS INDUSTRY IN CONSTANT AND CURRENT DOLLARS, 1964-1975.

($1000)

YEAR	FED FUNDS FOR PRIV AG R+D CURRENT $	FED FUNDS FOR PRIV AG R+D CONSTANT $
1964	1	1.2
1965	1	1.1
1966	3	3.2
1967	2	2.0
1968	2	1.9
1969	1	0.9
1970	3	2.5
1971	2	1.6
1972	1	0.8
1973	1	0.7
1974	1	0.7
1975	1	0.6

SOURCE: "TABLE B-6 FEDERAL FUNDS FOR R+D BY INDUSTRY :1964-75", RESEARCH AND DEVELOPMENT IN INDUSTRY 1975, P.33, NSF 77-324.

TABLE A-34 SAES FEDERAL FORMULA FUNDS FOR TOTAL, POST HARVEST TECHNOLOGY (PHT), PRODUCTION, AND OTHER RESEARCH IN CURRENT AND CONSTANT DOLLARS 1966-1979.

($MILLON)

	FORM TOTAL RES EXP		FORM PHT RES EXP		FORM PROD RES EXP		FORM OTHER RES EXP	
YEAR	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1966	48.017	50.3851	10.877	11.4134	31.287	32.8300	5.853	6.1417
1967	48.694	48.6940	11.286	11.2860	30.882	30.8820	6.526	6.5260
1968	52.449	49.6676	11.505	10.8949	34.418	32.5928	6.526	6.1799
1969	53.912	48.3516	11.877	10.6520	34.459	30.9049	7.576	6.7946
1970	56.439	46.8373	12.420	10.3071	36.042	29.9104	7.977	6.6199
1971	62.743	48.6003	14.124	10.9404	38.117	29.5252	10.502	8.1348
1972	70.587	51.2614	16.465	11.9572	41.440	30.0944	12.682	9.2099
1973	77.220	52.4592	18.940	12.8668	44.126	29.9769	14.154	9.6155
1974	82.127	50.3538	20.284	12.4365	45.975	28.1882	15.868	9.7290
1975	90.302	50.8744	20.802	11.7194	52.173	29.3932	17.327	9.7617
1976	102.505	54.4371	24.810	13.1758	57.020	30.2815	20.675	10.9798
1977	116.761	58.1769	28.183	14.0424	67.445	33.6049	21.133	10.5296
1978	132.179	60.8279	24.815	11.4197	86.432	39.7754	20.932	9.6328
1979	142.735	60.6609	22.809	9.6936	99.510	42.2907	20.416	8.6766

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-35 SAES COOPERATVE GRANTS AND COOPERATIVE AGREEMENTS (CGCA) FUNDS FOR TOTAL, POST HARVEST TECHNOLOGY(PHT), PRODUCTION, AND OTHER RESEARCH IN CURRENT AND CONSTANT DOLLARS 1966-1979.

($MILLON)

YEAR	CGCA TOTAL RES EXP CUR $	CGCA TOTAL RES EXP CONST $	CGCA PHT RES EXP CUR $	CGCA PHT RES EXP CONST $	CGCA PROD RES EXP CUR $	CGCA PROD RES EXP CONST $	CGCA OTHER RES EXP CUR $	CGCA OTHER RES EXP CONST $
1966	6.008	6.30430	1.559	1.63589	3.926	4.11962	0.523	0.54879
1967	6.260	6.26000	1.707	1.70700	4.004	4.00400	0.549	0.54900
1968	9.594	9.08523	1.835	1.73769	6.850	6.48674	0.909	0.86080
1969	7.784	6.98117	1.611	1.44484	5.310	4.76233	0.863	0.77399
1970	6.837	5.67386	1.467	1.21743	4.727	3.92282	0.643	0.53361
1971	6.320	4.89543	1.170	0.90627	4.495	3.48180	0.655	0.50736
1972	6.850	4.97458	1.548	1.12418	4.548	3.30283	0.754	0.54757
1973	7.476	5.07880	1.527	1.03736	4.721	3.20720	1.228	0.83424
1974	8.631	5.29185	1.639	1.00490	5.364	3.28878	1.628	0.99816
1975	10.773	6.06930	1.814	1.02197	6.827	3.84620	2.132	1.20113
1976	9.882	5.24801	1.423	0.75571	6.998	3.71641	1.461	0.77589
1977	11.758	5.85850	1.745	0.86946	7.948	3.96014	2.065	1.02890
1978	14.783	6.80304	2.540	1.16889	8.722	4.01381	3.521	1.62034
1979	17.827	7.57629	3.007	1.27794	11.237	4.77561	3.583	1.52274

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-36 OTHER FEDERAL COOPERATIVE GRANTS AND AGREEMENTS FOR POST HARVEST TECHNOLOGY(PHT), PRODUCTION, OTHER, AND TOTAL RESEARCH AT SAES IN IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($MILLON)

	OTH FED TOTAL RES EXP		OTH FED PHT RES EXP		OTH FED PROD RES EXP		OTH FED OTHER RES EXP	
YEAR	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1966	24.522	25.7314	5.050	5.29906	16.584	17.4019	2.888	3.03043
1967	23.566	23.5660	5.158	5.15800	15.517	15.5170	2.891	2.89100
1968	28.602	27.0852	6.561	6.21307	18.900	17.8977	3.141	2.97443
1969	27.834	24.9632	6.785	6.08520	16.545	14.8386	4.504	4.03946
1970	26.440	21.9419	5.782	4.79834	17.613	14.6166	3.045	2.52697
1971	25.957	20.1061	6.581	5.09760	16.514	12.7916	2.862	2.21689
1972	27.299	19.8250	6.243	4.53377	17.462	12.6812	3.594	2.61002
1973	28.748	19.5299	6.739	4.57812	18.680	12.6902	3.329	2.26155
1974	31.205	19.1324	6.117	3.75046	20.010	12.2685	5.078	3.11343
1975	34.236	19.2879	6.573	3.70310	23.153	13.0439	4.510	2.54085
1976	37.772	20.0595	7.744	4.11259	24.952	13.2512	5.076	2.69570
1977	51.759	25.7892	10.766	5.36423	35.038	17.4579	5.955	2.96712
1978	53.590	24.6618	11.362	5.22872	32.653	15.0267	9.575	4.40635
1979	56.165	23.8695	12.667	5.38334	35.851	15.2363	7.647	3.24989

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-37 SAES TOTAL REGIONAL RESEARCH FUNDS(RRF) FOR POST HARVEST TECHNOLOGY(PHT), PRODUCTION, OTHER, AND TOTAL RESEARCH IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

	TOTAL RRF PHT RES EXP		TOTAL RRF OTHER RES EXP		TOTAL RRF PROD RES EXP		TOTAL RRF OTHER RES EXP	
YEAR	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1966	3062	3213.01	831	871.98	5843	6131.16	9736	10216.2
1967	2988	2988.00	746	746.00	5256	5256.00	8990	8990.0
1968	3089	2925.19	857	811.55	6186	5857.95	10132	9594.7
1969	3197	2867.26	962	862.78	6123	5491.48	10282	9221.5
1970	3420	2838.17	1057	877.18	6448	5351.04	10925	9066.4
1971	3948	3058.09	1580	1223.86	6853	5308.29	12381	9590.2
1972	4558	3310.09	2088	1516.34	6952	5048.66	13598	9875.1
1973	4814	3270.38	2272	1543.48	7442	5055.71	14528	9869.6
1974	4761	2919.07	2156	1321.89	7837	4805.02	14754	9045.9
1975	5184	2920.56	2433	1370.70	8811	4963.94	16428	9255.2
1976	5700	3027.08	2589	1374.93	9841	5226.23	18130	9628.3
1977	6365	3171.40	3004	1496.76	12273	6115.10	21642	10783.3
1978	6532	3005.98	3542	1630.00	14327	6593.19	24401	11229.2
1979	5841	2482.36	3227	1371.44	14265	6062.47	23333	9916.3

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-38 SAES NORTHEAST REGIONAL RESEARCH FUNDS(RRF) FOR POST HARVEST TECHNOLOGY(PHT), PRODUCTION, OTHER, AND TOTAL RESEARCH IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

	NE RRF PHT RES EXP		NE RRF OTHER RES EXP		NE RRF PROD RES EXP		NE RRF TOTAL RES EXP	
YEAR	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1966	631	662.120	185	194.124	1251	1312.70	2067	2168.94
1967	478	478.000	284	284.000	1013	1013.00	1775	1775.00
1968	594	562.500	260	246.212	1287	1218.75	2141	2027.46
1969	715	641.256	240	215.247	1217	1091.48	2172	1947.98
1970	827	686.307	259	214.938	1199	995.02	2285	1896.27
1971	912	706.429	408	316.034	1273	986.06	2593	2008.52
1972	1041	755.991	492	357.298	1275	925.93	2808	2039.22
1973	1115	757.473	600	407.609	1312	891.30	3027	2056.39
1974	1086	665.849	658	403.433	1346	825.26	3090	1894.54
1975	1237	696.901	719	405.070	1446	814.65	3402	1916.62
1976	1479	785.449	711	377.589	1607	853.43	3797	2016.46
1977	1612	803.189	782	389.636	1990	991.53	4384	2184.35
1978	1669	768.063	936	430.741	2289	1053.38	4894	2252.19
1979	1502	638.334	914	388.440	2446	1039.52	4862	2066.30

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-39 SAES SOUTHERN REGIONAL RESEARCH FUNDS(RRF) FOR POST HARVEST TECHNOLOGY(PHT), PRODUCTION, OTHER, AND TOTAL RESEARCH IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

YEAR	SO. RRF PHT RES EXP		SO. RRF OTHER RES EXP		SO. RRF PROD RES EXP		SO. RRF TOTAL RES EXP	
	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1966	960	1007.35	300	314.795	1577	1654.77	2837	2976.92
1967	1042	1042.00	207	207.000	1422	1422.00	2671	2671.00
1968	1024	969.70	247	233.902	1583	1499.05	2854	2702.65
1969	1051	942.60	272	243.946	1559	1398.21	2882	2584.75
1970	1156	959.34	338	280.498	1657	1375.10	3151	2614.94
1971	1181	914.79	464	359.411	1945	1506.58	3590	2780.79
1972	1197	869.28	637	462.600	2029	1473.49	3863	2805.37
1973	1267	860.73	747	507.473	2105	1430.03	4119	2798.23
1974	1414	866.95	725	444.513	2039	1250.15	4178	2561.62
1975	1612	908.17	798	449.577	2262	1274.37	4672	2632.11
1976	1755	932.02	866	459.904	2536	1346.79	5157	2738.71
1977	2025	1008.97	989	492.775	3411	1699.55	6425	3201.30
1978	2063	949.38	1277	587.667	3946	1815.92	7286	3352.97
1979	1910	811.73	1247	529.962	3792	1611.56	6949	2953.25

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-40 SAES NORTH CENTRAL REGIONAL RESEARCH FUNDS(RRF) FOR POST HARVEST TECHNOLOGY(PHT), PRODUCTION, OTHER, AND TOTAL RESEARCH IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

	N.C. RRF PHT RES EXP		N.C. RRF OTHER RES EXP		N.C. RRF PROD RES EXP		N.C. RRF TOTAL RES EXP	
YEAR	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1966	844	885.624	262	274.921	1439	1509.97	2545	2670.51
1967	868	868.000	179	179.000	1325	1325.00	2372	2372.00
1968	908	859.848	235	222.538	1511	1430.87	2654	2513.26
1969	847	759.641	291	260.987	1581	1417.94	2719	2438.57
1970	689	571.784	294	243.983	1847	1532.78	2830	2348.55
1971	1043	807.901	364	281.952	1803	1396.59	3210	2486.44
1972	1362	989.107	434	315.178	1793	1302.11	3589	2606.39
1973	1297	881.114	466	316.576	2063	1401.49	3826	2599.18
1974	1249	765.788	313	191.907	2317	1420.60	3879	2378.30
1975	1310	738.028	421	237.183	2608	1469.30	4339	2444.51
1976	1409	748.274	472	250.664	2939	1560.81	4820	2559.75
1977	1656	825.112	654	325.859	3464	1725.96	5774	2876.93
1978	1701	782.789	672	309.250	4254	1957.66	6627	3049.70
1979	1442	612.835	460	195.495	4092	1739.06	5994	2547.39

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-41 SAES WESTERN REGIONAL RESEARCH FUNDS(RRF) FOR POST HARVEST TECHNOLOGY(PHT), PRODUCTION, OTHER, AND TOTAL RESEARCH IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($1000)

	WEST RRF PHT RES EXP		WEST RRF OTHER RES EXP		WEST RRF PROD RES EXP		WEST RRF TOTAL RES EXP	
YEAR	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1966	627	657.922	84	88.143	1576	1653.73	2287	2399.79
1967	600	600.000	76	76.000	1496	1496.00	2172	2172.00
1968	563	533.144	115	108.902	1805	1709.28	2483	2351.33
1969	584	523.767	159	142.601	1766	1583.86	2509	2250.22
1970	748	620.747	166	137.759	1745	1448.13	2659	2206.64
1971	812	628.970	344	266.460	1832	1419.05	2988	2314.48
1972	958	695.715	525	381.264	1855	1347.13	3338	2424.11
1973	1135	771.060	459	311.821	1962	1332.88	3556	2415.76
1974	1012	620.478	460	282.036	2135	1309.01	3607	2131.65
1975	1025	577.465	495	278.873	2495	1405.63	4015	2261.97
1976	1057	561.338	540	286.776	2759	1465.22	4356	2313.33
1977	1072	534.131	579	288.490	3408	1698.06	5059	2520.68
1978	1099	505.752	657	302.347	3838	1766.22	5594	2574.32
1979	987	419.465	606	257.544	3935	1672.33	5528	2349.34

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-42 STATE APPROPRIATIONS FOR TOTAL, POST HARVEST TECHNOLOGY(PHT), PRODUCTION, AND OTHER RESEARCH AT SAES IN CURRENT AND CONSTANT DOLLARS, 1966-1979.

($MILLON)

YEAR	STATE TOTAL RES EXP		STATE PHT RES EXP		STATE PROD RES EXP		STATE OTHER RES EXP	
	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1966	117.942	123.759	14.022	14.7135	91.751	96.276	12.169	12.7692
1967	120.610	120.610	14.573	14.5730	91.667	91.667	14.370	14.3700
1968	142.276	134.731	16.428	15.5568	109.628	103.814	16.220	15.3598
1969	157.526	141.279	19.018	17.0565	118.610	106.377	19.898	17.8457
1970	178.666	148.271	20.512	17.0224	136.491	113.271	21.663	17.9776
1971	190.892	147.864	22.057	17.0852	145.126	112.414	23.709	18.3648
1972	226.185	164.259	27.825	20.2070	169.339	122.977	29.021	21.0755
1973	247.691	168.268	31.127	21.1461	184.132	125.090	32.432	22.0326
1974	288.022	176.592	36.471	22.3611	212.300	130.166	39.251	24.0656
1975	331.270	186.631	39.031	21.9893	250.655	141.214	41.384	23.4276
1976	349.502	185.609	42.086	22.3505	261.459	138.852	45.957	24.4063
1977	393.358	195.993	45.183	22.5127	299.557	149.256	48.618	24.2242
1978	428.394	197.144	51.302	23.6088	308.621	142.025	58.471	31.5099
1979	457.104	194.264	56.005	23.8015	340.780	144.828	60.319	25.6349

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

TABLE A-43 SAES PRIVATE INDUSTRY FUNDS FOR TOTAL, POST HARVEST TECHNOLOGY (PHT), PRODUCTION, AND OTHER RESEARCH IN CURRENT AND CONSTANT DOLLARS 1966-1979.

($MILLON)

	PRIVATE TOTAL RES EXP		PRIVATE PHT RES EXP		PRIVATE PROD RES EXP		PRIVATE OTHER RES EXP	
YEAR	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $	CUR $	CONST $
1966	8.726	9.1563	1.373	1.44071	6.271	6.5803	1.082	1.13536
1967	8.545	8.5450	1.484	1.48400	5.997	5.9970	1.064	1.06400
1968	9.766	9.2481	1.672	1.58333	6.033	5.7131	2.061	1.95170
1969	12.236	10.9740	2.258	2.02511	8.200	7.3543	1.778	1.59462
1970	13.719	11.3851	2.460	2.04149	9.140	7.5851	2.119	1.75851
1971	14.312	11.0860	2.179	1.68784	9.953	7.7095	2.180	1.68861
1972	16.021	11.6347	2.474	1.79666	10.875	7.8976	2.672	1.94045
1973	17.523	11.9042	3.119	2.11889	11.652	7.9158	2.752	1.86957
1974	20.624	12.6450	3.779	2.31698	13.492	8.2722	3.353	2.05579
1975	23.473	13.2242	3.972	2.23775	15.016	8.4597	4.485	2.52676
1976	27.459	14.5826	4.285	2.27562	19.234	10.2146	3.940	2.09241
1977	31.819	15.8540	4.592	2.28799	22.254	11.0882	4.973	2.47783
1978	33.587	15.4565	5.053	2.32536	22.416	10.3157	6.118	2.81546
1979	35.101	14.9176	5.333	2.26647	23.820	10.1232	5.948	2.52784

SOURCE: COMPILED FROM USDA, INVENTORY OF AGRICULTURAL RESEARCH FY1966-1979, VOL. II, SCIENCE AND EDUCATION ADMINISTRATION.

APPENDIX B

An Outline of the SAES Budget Process
(Modified for 1980, 1981, and 1982)
from
H. R. Fortmann, The Dictionary
Northeastern Regional Association of Agricultural
Experiment Stations
229-B Agricultural Administration Bldg.
University Park, Pennsylvania 16802
(Fourth Revision, February 28, 1978)

THE BUDGET PROCESS
AN OUTLINE OF THE SAES FEDERAL BUDGET PROCESS

	APPROXIMATE TIME WHEN ACTIONS TAKE PLACE		
ACTIONS PERTAINING TO SAES FEDERAL BUDGET	For FY 1980 BUDGET 10-1-79 to 9-30-80	For FY 1981 BUDGET 10-1-80 To 9-30-81	For FY 1982 BUDGET 10-1-81 To 9-30-82
1) Tentative levels for budget set	Feb. 1977	Feb. 1978	Feb. 1979
2) SAES budget request approved by Experiment Station Section, & by Division of Agriculture of NASULGC	2nd Week In Nov. 1977	2nd Week In Nov. 1978	2nd Week In Nov. 1979
3) ESCOP Legislative Subcommittee presents SAES budget statement to Executive Committee of NASULGC	Jan. 1978	Jan. 1979	Jan. 1980
4) Information collected from SAES Directors on high priority needs & the use that would be made of funds which would come to their station at proposed levels. By Research Programs RPA's and Commodities	April-May 1977	April-May 1978	April-May 1979
5) Budget request assembled by ESCOP Legislative Subcommittee by Research Programs & special packages, e.g., Environmental Quality, Food & Nutrition, & Beef	June-July 1978	June-July 1979	June-July 1980
6) SAES budget request submitted by CSRS to USDA budget committee	August 1978	August 1979	August 1980
7) Assorted negotiations between USDA (Secretary's) budget Committee & OMB to finalize the Executive Budget (President's Budget). The final decision become "privileged" (confidential) information about September 20.	Aug.-Sept. 1978	Aug.-Sept. 1979	Aug.-Sept. 1980
8) Representatives of the ESCOP Legislative Subcommittee appear before representatives of OMB to explain & defend the SAES budget request	Sept. 29 1978	Sept. 27 1979	Sept.-Oct. 1980
9) The Executive budget (President's Budget) is announced	Last Week In Jan. 1979	Last Week In Jan. 1980	Last Week In Jan. 1981
10) Review SAES Federal Budget request in NISARC	1st Week In Feb. 1978	1st Week In Feb. 1979	1st Week In Feb. 1980

An Outline of the SAES Federal Budget Process (continued)

ACTIONS PERTAINING TO SAES FEDERAL BUDGET	For FY 1980 BUDGET 10-1-79 To 9-30-80	For FY 1981 BUDGET 10-1-80 To 9-30-81	For FY 1982 BUDGET 10-1-81 To 9-30-81
11) Review Executive budget & consider desirability of & courses of action for testifying before Committees of Congress at NISARC meeting	1st Week In Feb. 1979	1st Week In Feb. 1980	1st Week In Feb. 1981
12) ESCOP Legislative Committee appears to explain, justify & urge inclusion of the budget items originally requested. First before the House Subcommittee for Agricultural appropriations & then before the Senate Subcommittee	March-May 1979	March-May 1980	March-May 1981
13) Hearings are scheduled by the House & Senate Subcommittee for private individuals, industries & organizations to testify for or against budget requests. Additions to or deletions from the Executive Budget can be recommended	March-May 1979	March-May 1980	March-May 1981
14) House & Senate pass on Agricultural Appropriations Bill	May-Sept. 1979	May-Sept. 1980	May-Sept. 1981
15) Conference action by House & Senate to resolve differences	After passage of separate bills	After passage of separate bills	After passage of separate bills
16) President signs Appropriations Bill	After passage of separate bills	After passage of separate bills	After passage of separate bills

NOTE: Actions pertaining to the budget requests for three separate fiscal years are taking place concurrently at any point in time.

NOTES: FOR SAES FEDERAL BUDGET PROCESS

A. The SAES Federal Budget Request involves the following pieces of enabling legislation: All administered by CSRS. See legislation for special requirements.

1) The Hatch Act as Amended in 1955 - P.L. 84-352 (84th Congress). Funds distributed by formula to the 55 SAES. 25% of increases for Regional Research (conducted by two or more states.)

2) The McIntire-Stennis Act - P.L. 87-788. Funds distributed by formula to eligible institutions.

3) The Physical Facilities Act - P.L. 88-74. Funds distributed by formula to the 55 SAES. For new facilities and renovations.

4) The Special Grant Act - P.L. 89-106. Distributed as competitive grants.

5) The Rural Development Act - P.L. 92-419. Funds for Research and Extension under Title 5 allocated by formula to each State for Approved Programs.

6) Food and Agriculture Act of 1977 - P.L. 95-113. Title XIV. Analysis of Provisions of the National Agricultural Research, Extension and Teaching Policy Act of 1977. Provides all of the above and authorizes additional funding.

CHRONOLOGICAL SERIES OF EVENTS IN THE SAES FEDERAL BUDGET PROCESS

(Dates when events take place are generally approximate and dependent on preceding events. In some cases, the date given is simply the starting point for a series of activities which may extend over several months. In other cases, the date given indicates the sequence for the event on the assumption that previous events have been completed. Many activities are independent of the others.)

JANUARY:

Item 3 - ESCOP Legislative Subcommittee presents SAES Budget Request to Executive Committee of NASULGC. For Budget 2 years ahead.

Item 9 - The President's "Executive Budget" for next fiscal year is announced.

FEBRUARY:

Item 1 - Tentative levels for SAES and USDA Budget Requests are set -- for budget 3 years ahead.

Item 10 - Review SAES Federal Budget request in NISARC meeting. For budget 2 years ahead.

Item 11 - Review Executive Budget as it pertains to SAES in NISARC meeting. For budget 1 year ahead.

MARCH:

Item 12 - ESCOP Legislative Subcommittee appears before House and Senate Agricultural Appropriation Subcommittees. On budget for next fiscal year. (Hearings may be carried over to April or May.)

Item 13 - Hearing before House and Senate Appropriations Subcommittee for private individuals, organizations, and industry representatives to testify about budget for next fiscal year. (Hearings may be carried over to April or May.)

APRIL:

Items 12 & 13 - See March above.

Item 4 - Begin collection of information from SAES Directors on high priority needs and use that would be made of funds that would come to their station at proposed levels for fiscal year three years ahead. (By RP's, RPA's and Commodities, etc.)

MAY:

Items 12 & 13 - See March above.

Item 4 - See April above.

Item 14 - House and Senate pass on Agricultural Appropriations Bill for fiscal year beginning October 1. This event may not take place for some weeks or months. It has been delayed for as long as 6 months after the start of the fiscal year. Hopefully, shifting the start of the fiscal year to October 1 will enable Congress to provide timely passage of the budget.

JUNE:

Item 14 - See May above.

Item 5 - SAES Budget request, for fiscal year one year ahead, assembled by ESCOP Legislative Subcommittee. (By RP's and special packages.)

JULY:

Item 5 - See June above.

Item 14 - See May above.

AUGUST:

Item 6 - SAES Budget Request for fiscal year, one year ahead, submitted by CSRS to USDA Budget Committee.

Item 7 - Negotiations between USDA Budget Committee and OMB about SAES (& USDA) budget to be incorporated into President's Executive Budget for next fiscal year. The final decision becomes "confidential" about Sept. 20.

AUGUST: (cont'd) Item 14 - See May above.

SEPTEMBER: Item 7 - See August above.

Item 14 - See May above.

Item 15 - Conference Action by House and Senate to resolve differences in Agricultural Appropriations bills passed by separate houses.

Item 16 - President signs Agricultural Appropriations Bill. Items 15 and 16 take place only after 14.

OCTOBER: Item 8 - Representatives of the ESCOP Legislative Subcommittee (along with those from the Division, ECOP, and Colleges of 1890) appear before OMB to explain and defend the SAES budget request for the next fiscal year.

Items 14 15 & 16 - See above.

NOVEMBER: Item 2 - SAES budget request approved by Experiment Station Section, and by Division of Agriculture. For fiscal year two years ahead.

Items 14 15 & 16 - See above.

DECEMBER: Items 14 15 & 16 - See above. Hopefully, all have been completed for the fiscal year which began the previous October 1.

Item 17 - ESCOP Legislative Subcommittee and all SAES Directors contemplate the extent to which their various efforts have succeeded in obtaining the funds to enable the SAES scientists to serve the current and future needs of Americans and to provide for an acceptable future for the generations to come who can inherit only the way of life and the kind of earth this generation leaves to it!!!

The process of events in the new budget cycle is shown below:

On or Before:	Action to be Completed:
November 13	President submits current services budget.
December 31	Joint Economic Committee's economic evaluation of current services budget.
15th day after Congress meets	President submits his budget.
March 15	Committees and joint committees submit reports to Budget Committees.
April 1	Congressional Budget Office submits report to Budget Committees.
April 10	President's amendments to budget.
April 15	Budget Committees report first concurrent resolution on the budget to their Houses.
May 15	Committees report bills and resolutions authorizing new budget authority.
May 15	Congress completes action on first concurrent resolution on the budget.
July 15	President's additional amendments to budget.
7th day after Labor Day	Congress completes action on bills and resolutions providing new budget authority and new spending authority.

September 15..................	Congress completes action on second required concurrent resolution on the budget.
September 25..................	Congress completes action on reconciliation bill or resolution, or both, implementing second required concurrent resolution.
October 1.....................	Fiscal year begins.
As soon after October 1 as practicable...............	Congressional Budget Office presents 5 year projections.

Commissioned Paper II

AN EVALUATION OF METHODS FOR EXAMINING THE QUALITY OF AGRICULTURAL RESEARCH

Robert E. Evenson and Brian Wright

Office of Technology Assessment

December 1980

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Summary

This paper attempts an evaluation of methods for examining the quality of agricultural research with special reference to post-harvest technology research. We understand that there is a body of congressional concerns that U.S. agricultural research is not well managed, coordinated, or planned. There is a further implicit presumption that this agricultural research is of low quality either in some obsolete sense or in comparison with other fields.

Our brief perusal of the literature failed to turn up any formal methods for evaluating or even defining the quality of research. It appears that the perception that agricultural research is of low quality is based on informal or quasi-formal judgments. Such judgments, particularly those which are made in the context of peer review procedures are an important part of the process of scientific advances. They serve to guide science in particular directions and to facilitate a verification process. The value of these review processes for purposes of comparing research quality across disciplines, or for judging the economic value of research, is much less obvious.

We were faced with a choice in approaching our topic. On the one hand we could have accepted the informal review system as the only viable method for evaluation quality and then produced a review of the reviewers as it were. We would then have added our own subjective judgments to those of others and looked for consensus among evaluations. A second choice was to attempt to develop more objective methods for evaluating research quality. This would require an effort to impose some structure on the problem by trying to define quality in economic terms and then looking for objective quantitative measures.

We opted for the second choice in spite of its obvious drawbacks. Perhaps most seriously we had to recognize that we would lose much of our audience because we would have to resort to formalization and the use of economic concepts. We also recognized that we were, in effect, having to initiate a research effort on our own, one which would not necessarily have pay-off given the limited time and resources. We concluded that, in spite of these problems, even small progress in the direction of objective formalization would be more useful than anything that we might contribute in terms of our own informal judgments.

The methods of research quality evaluation in a particular research discipline (or subdiscipline) are themselves quite objective and in some cases, even quite formal. Reviewers of journal papers, for example, form judgments as to quality of submitted manuscripts. Such criteria as clarity, elegance and rigor are applied. Reviewers look for errors in logic, mistakes in the application of statistical methods, etc. In general, originality is also given some weight.

It is important to note, however, that research programs, particularly applied research programs, are composed of a number of research disciplines and work disciplines. Furthermore, some of these applied disciplines are in effect multiple or mixed disciplines with specific applied research objectives. These disciplines have different and sometimes conflicting objectives. In the less applied disciplines, useful knowledge in the form of new technology or new managerial or policy information is given little weight. In such disciplines the scientific publication is the sole indicator of output and the publicating review process and the citation process provides the architecture for the growth of knowledge.

At the other end of the spectrum, the discipline may be solely interested in producing new technology. The scientific paper may have limited relevance in such a discipline and much of the published output may be of a reporting nature. Also, such disciplines tend to produce extension type literature, i.e., literature for an audience broader than the discipline. The scientific paper plays a lesser role in guiding research project development in these disciplines, which may also respond quite directly to the interests of a clientele. Asparagus growers in California would be an example of a clientele group which can make demands on an applied research discipline.

We find it convenient to distinguish between the evaluation of research quality within narrowly defined disciplines and the evaluation of quality in a research program encompassing several disciplines.

Consider first the meaning of quality within a narrowly defined discipline or research area. Each discipline will have developed its own criteria for research quality. These criteria will be applied to the publications of scientific papers and to some extent to the evaluation of research proposals. A well organized research area will have developed consistant research objectives and research quality criteria. These objectives will take into account the nature of

the specialized niche which the research area has in the larger scheme of the research program.

Even in a well organized research discipline, research quality as measured in the discipline itself will vary by researcher and by research institution. It will vary by age and by type of graduate training. The real world problem of the outdated and unmotivated "deadwood" exists in spades in research organizations. Furthermore, since many research disciplines are specialized on applied problems, they may have little control over the "research potential" which they work with and even high quality researchers may find it increasingly difficult to produce research and output because their potential is exhausted.

Simple measures of research output per unit of input such as publications, patents, new varieties, etc., per SMY, are indicators of quality only in a restricted sense. They are subject to the exhaustive phenomenon and to the problem that "supply creates its own demand". An expansion in the number of scientists in a discipline may create an increase in the demand for journals and related publications, but not necessarily in the real products of the system. In our research work as part of this paper we utilized patents and citations as output measures to avoid some of the worst problems. Patents are granted by examiners from outside the discipline and are more reliable indexes of certain types of research products. Citations are also determined particularly outside the discipline and have other desirable features.

In some fundamental sense, the more important questions regarding research quality have to do with both the organization and design of research disciplines or areas within larger research programs and with the consistency of the research objectives and quality criteria of each discipline to the objectives of the overall research program.

The design of an effective research program is an extremely difficult problem. We know some of the principles on which such programs should be based, but are not really in a position to "plan" research in a conventional sense. Actually, the agricultural research system of the U.S. represents one of the few cases where a large number of research disciplines and sub-disciplines are institutionally related to each other. The USDA-SAES system has evolved its structure over a long period of time in response to pressures from its ultimate clients, the producers and consumers of food and fibre products. It has developed a complex range of disciplines and sub-disciplines, each with its own quality criteria.

Crop improvement work, for example, is primarily done in Plant Breeding and Agronomy disciplines. However, the closely related disciplines of Plant Pathology, Soils Science and Entomology are very much part of the crop improvement system. Within each of these disciplines, subdisciplines with somewhat different quality criteria exist. Further, experiment stations have also incorporated plant physiology and other biological sciences in their institutional structure in an effort to produce new discovery potential. These disciplines exist outside the USDA-SAES system, as well, and different quality standards may be applied by the two groups.

There is an unfortunate tendency among scientists to apply quality standards suited to one discipline to related disciplines. The quality standards for publication in the "mother" disciplines are generally regarded to be higher than is the case for the subsidiary discipline. In a well organized research system, they should be. It is, however, the case that applied disciplines usually are subject to a certain amount of criticism from the basic disciplines which is part of general snobbery of the sciences.

The fact that agricultural sciences are subject to criticism then is hardly surprising. What has to be determined is whether they are subject to legitimate criticism, legitimate in the sense that an agricultural research discipline is not demanding scientific rigor and other quality standards that are appropriate to its mission. On this point we may note that there is always an age distribution problem in any sicence which is experiencing change. Many older scientists will not have the incentives to maintain themselves at the research frontier of a more basic science (in fact many will not maintain themselves at the applied frontier). New scientists, recently trained at this frontier are required to keep an applied field lively. There is thus a natural time lag in the application of new research quality standards in applied fields of research.

The pattern of hiring in many agricultural science fields is one of rapid expansion in the 1950's with slower expansion in the 1960's and almost no expansion in the 1970's. This has burdened the U.S. agricultural research system with an unfavorable age distribution. Another factor influencing judgments of quality of the system is the nature of the State Experiment Station System with much apparent duplication of effort and limited coordination of the effort.

The argument has been made elsewhere (Evenson, Waggoner, Ruttan (Science)) that much of this duplication is more apparent than real because of the limited transferability of technology. It can be quite efficient to have a number of parallel research efforts underway. It is even more efficient if these programs are actively producing improved technology targeted to local economic and climatic conditions. Perhaps more importantly, the SAES programs enable clientele interests to be expressed far more effectively than a federal system could. This is a strength of the system. This argument holds with much less force for post-harvest technology research, of course.

As we considered the larger question regarding the quality of agricultural research, it was clear that it would be difficult to fully identify the legitimate criticisms of the more basic disciplines. It was also apparent that state and federal perspectives regarding agricultural research differed because of the role of interest groups and that congressional concerns and state concerns may differ for legitimate reasons. We were also aware that overall productivity growth in agriculture has been quite rapid. The agricultural sector has quite clearly outperformed all other sectors by most reasonable total factor productivity measures in the past 7-8 years.

We have been asked to focus on post-harvest technology research. For these research fields, the location-specific character of the research is often less critical and thus the state interest groups concerns are less important. As a consequence, the USDA Utilization Labs tend to dominate PHT research and SAES research programs tend to be of lesser magnitude and importance than pre-harvest research.

The objectives of the PHT research programs are generally stated in terms of new and improved products, testing of foods and food additives, improved textile products and other chemicals. Since much of this research will produce new technology which is patentable, we felt that it would be important to look at patents in PHT areas granted to the USDA, SAES and private firms. We recognized that this is only a partial measure of the output of PHT research, but it is a very important part. Furthermore, since public PHT research is conducted in the presence of rather large private investments in PHT research, the two types of research should be related. High quality public PHT research should produce inventions which are pilot in nature. Public patents should be frequently cited by subsequent private patents as the private sector carries out further research. Public publications should also be cited by subsequent private publications and patents.

We collected detailed data for all USDA patents in 4 PHT technology fields (food, textiles, other chemicals, other), for the years 1966-68 and 1977-79, and for a sample of 80 private U.S. firm patents and 61 patents to foreign firms in two of the technology fields (food and textiles). We had information on the class of the patent, on the patents and other references which were cited by patent examiners as "next best art" and on the number of times a patent was subsequently cited by other patents.

Most of the U.S. patents in PHT are from private firms. The USDA labs account for only 5 percent of representative PHT patenting. State stations account for very few patents and patents per dollar expended on research are higher in the USDA than in the SAES units. We do not have comparative data for private R & D but would judge that patents per dollar of R & D are substantially higher in the private sector.

Our data allowed a number of qualitative comparisons of interest. Perhaps the most important was that a high proportion of patents are subsequently cited. For patents granted in 1966-68, only 22 percent of the USDA food patents and 30 percent of the private patents were not subsequently cited. For textiles, only 34 percent of the USDA and 18 percent of the private patents were not subsequently cited. Private patents were cited slightly more often than USDA patents. but these data suggest that most patented inventions do contribute to technology improvement.

Our data also show that 28 percent of the cited "next best art" patents for USDA patents in 1966-68 were other USDA patents and that this had grown to 35% by 1977-79. However, U.S. private patents cited USDA patents 19 percent of the time in 1975-79. This indicates that USDA patents were a significant part of the invention structure of the private sector. (We do not have data on the total number of relevant private patents, but USDA patents were probably less than 19 percent of the citable pool). Foreign origin patents, on the other hand, cited USDA patents less frequently. USDA patents also cited fewer total patents than either the U.S. private or foreign patents.

Our data do show a decline in the number of patents granted to USDA units from 1966-68 to 1977-79. They also show an increase in the proportion of foreign patents cited by USDA patents although private patents continue to have a higher foreign influence factor. PHT patenting is similar to more general patterns observed in patenting data in this regard. We do not have an explanation for the decline in USDA patenting.

We, of course, do not wish to base general conclusions regarding research quality on patent data alone. It is important, however, to stress two points here. First, public sector PHT research units are asked to invent new technology. Second, the standards for patentability are applied outside the PHT system. There is then something to be said for looking at these data as part of a broader evaluation.

Our second study of PHT research was a study to publications and more important of citations.

This study was more comprehensive than our patent study in two respects. First, we were able to obtain an SAES sample along with a USDA sample and secondly, published output is a more complete measure of researcher output. Data sources dictated that we collect data by individual researchers. Our procedure was first to obtain a list of research project principle investigators from CRIS data for 3 PHT RDA's. Then given this list of names for different periods, we went to citation abstracts to record data on the number of times the publications of these scientists were cited in 1979. We thus had data on citations of relatively recent published papers as well as citations of papers published in earlier periods. Both publications and citations are "screened" in the sense that we chose major journals in four areas covered by PHT research from which to draw citation abstracts.

Using these data we developed statistical models to test whether recent citations per scientist were related to institutional affiliation USDA or SAES. When we used citations of earlier papers and age of the investigator as control variables, we found no significant affect of institutional setting on total citations per SMY or on citations per publication. When we included expenditures per SMY as a variable measuring the support per scientist in terms of equipment, assistance, etc., we found that this variable did not affect publication per SMY but that it did positively affect citations per publication and total citations per SMY.

Citations of early work were considered to be an index of "personal" productivity or quality of the researcher in question and these were significant determinants of citations of later work. We also found that diversity of citations, i.e., citations in fields other than the field of the publication, was affected by personal characteristics.

The two studies undertaken as part of our effort to look at more objective evidence or research quality do not provide conclusive answers to the question at hand. They do, however, we think, add something to the pool of other less formal and more judgmental evidence on research quality. We find these data consistent with the view that many PHT researchers are not at the research frontier and that some research programs may be poorly organized. But they surely are not consistent with the highly critical view that PHT research is producing little of value. It is providing patents which are subsequently cited by the private sector. It is producing a body of scientific literature which is roughly comparable with that produced in other applied work.

The SAES system does not appear to be providing research environments which are superior to the USDA environments. Our impression is that this story might be quite different for preharvest technology research.

Ultimately, the line of research initiated in this paper can be extended to address other questions. If a basic research discipline is to be justified on the grounds that it produces knowledge which is useful to applied researchers then applied researchers should be citing the basic literature. Further, there should be some reverse citation. Similar comments can be made regarding patents and the private sector. Quality of research is not just a matter of peer determination. One could also utilize citation data to investigate spatial issues. If research in different states (or different countries) are citing each other, this is important information. Perhaps one day we will be able to pursue the general question of optimal mixes of disciplines, optimal quality standards and scientific training in a fully systematic way.

I. Introduction

The term "quality of research" means different things in different contexts. To an economist, evaluating the benefits stream associated with a particular research program, quality may mean the relationship between program benefits and program resources. High quality research is that research which yields a high ratio of benefits to costs. To a scientist, quality is measured by conformity to standards established by scientific work at the "frontier" of the discipline. These standards vary by discipline and generally depend on the extent to which the discipline is "applied."

It is of course quite possible for these definitions of quality to be inconsistent with one another. To the economist, it makes sense to sacrifice scientific quality to obtain more economic quality if that is a feasible choice. A highly applied research area may develop its own distinctive quality standards which may appear to be low in quality from the perspective of a less-applied but related science. From the perspective of the applied science, however, its standards are justified by their usefulness in enabling more rapid progress toward applied technology-oriented objectives.

In this paper we are attempting to evaluate methods and procedures for examining the quality of research. As economists our ultimate concern is whether public sector agencies such as the USDA and the State Experiment Stations are obtaining as many benefits as possible given the resources invested. More particularly we are interested in knowing whether a change in the quality of research as understood by scientists would lead to an improvement in the quality of research as defined by economists.

The following section of this paper is a brief review of the existing literature on research project evaluation. The next section is directed toward a clarification of conceptual issues surrounding quality and to some suggestions regarding its measurement. This is followed by an empirical study of patented inventions by USDA and other public agencies in post-harvest technology. We then report the results of a "pilot" study of publications and citations of publications by USDA agencies and State Experiment Stations. A final section provides a summary of findings and suggestions for further work on the topic.

II. Previous Studies: A Brief Study

A recent exhaustive review of studies of agricultural research by George Norton and Jeff Davis (1979) includes more than 180 papers in its bibliography. The authors discuss these studies according to whether they use *ex post* (consumers' and producers' surplus techniques and regression methods) or *ex ante* study of potato storage research) explicitly dealt with post-harvest technology research. Furthermore, none of the studies directly dealt with the question of research quality.

It is possible that other studies have dealt with post-harvest technology research in meat packing and related fields, but we are not aware of specific studies at this time. A number of *ad hoc* calculations and claims have no doubt been made regarding new products, etc.

It is also quite possible that studies in the History of Science or Sociology of Science have investigated research quality in different organizations. Again, however, we know of none which have directly investigated research quality in agricultural research institutions. An unpublished paper by Paul Waggoner, Director of the Connecticut Agricultural Experiment Station a few years ago, and another unpublished paper by R. Evenson and Finis Welch, provided some pertinent calculations. We will report and expand these calculations as part of this report to provide a basis for comparison between production or pre-harvest research and post-harvest research.

The key factor in the validity of the numbers of scientific publications as a substantive measure of research activity is that a standard of quality be applied to the inclusion of publications in the measure. For years, the annual report of the State Experiment Stations has included a table of the number of scientific publications by station. A casual inspection of these data readily shows that they have not been subjected to any standards of quality. The report simply accepts the data provided by each state. Measures of this sort are quite meaningless.

On the other hand, when standards are applied these measures have proven to be quite useful. Two sets of "quality screened" scientific publications data have been collected. The first set is tabulated from a set of leading agricultural journals. It is the total number of publication over the five year period 1958-1962 published in the following journals:

Table 1: Abstracted Publications by Commodity

Commodity	Total Commodity Oriented Publications (Annual) 1949-53	1954-58	1959-63	1964-68	Thousands of 1939 Dollars per Publication 1951	1961	1966+	Pub. per Scientist Man-Year 1966
Corn*	107	92	129	194			9.1	.95
Sorghum*	21	17	38	51			21.7	1.21
Wheat*	11	17	28	69			33.2	.53
Barley*	42	41	42	77			38.7	.72
Rice*	9	8	11	13			52.7	.51
Cereals	190	165	287	404	21.2	23.0	34.8	.79
Potatoes*	72	38	45	50	11.4	19.4	42.0	.98
Tomatoes*	8	28	36	88	-	-	-	-
Sugar Crops*	36	30	24	30	7.8	10.0	88.3	.34
Cotton*	44	38	48	99	26.4	30.8	107.6	.33
Soil Science**	230	235	271	324	-	-	-	.82
Phytopathology**	333	367	726	879	-	-	-	1.22
Dairy***	700	989	1043	n.a.	6.3	7.3	15.4	2.91
Poultry**	158	166	206	180	34.8	38.8	79.8	.33
Animal Production**	175	174	304	447	-	-	-	.51

*Abstracted in _Plant Breeding Abstracts_

**Abstracted in _Biological Abstracts_

***Abstracted in Dairy _Science Abstracts_

+Not comparable to 1951 and 1961 data, which do not include U.S.D.A. research.

Crop-related journals:
- Journal of the American Society of Agronomy
- Soil Science
- Journal of Am. Sec. of Soil Scientists
- Horticulture
- Phytopathology
- Plant Physiology
- Entomological Society of American-Annals

Livestock-related journals:
- Journal of Dairy Science
- Journal of Poultry Science
- Journal of Animal Science

The second set of publications is compiled from three major International Abstracting Journals, Plant Breeding Abstracts, Biological Abstracts and Dairy Science Abstracts. A summary of these data for the United States by commodity and source is presented in Table 1. In addition to the total numbers of publications for 5-year periods, we provide some additional computations. For several of the commodities, it was possible to calculate expenditures per publication. First, we have only a sample of the publications by commodity. We have a reasonably representative sample, we believe, since the abstracting journals cover a large number of journals. In any case there are probably some errors from this source.

Second, even if the publications and research spending were reasonably well-matched, there are systematic variations in both expenditures per scientist man-year and in scientist man-years per publication. Variations in expenditures per scientist are largely determined by the mix of crop-related and livestock-related research. Variations in publications per scientist man-year, on the other hand, may be due to the quality of the scientist, organizational characteristics of the research unit, or to publishing standards and traditions. If we are examining national average data, as in Table 1, most of the variation in this ratio between commodities should be associated with publishing standards and with the particular screening system applied. Our calculations show a fair amount of such variation. Publications in dairy science, for example, are subject to significantly different standards than those for most other categories.

In Table 2 we present the publications by region for the two sets. The variation in publications per scientist man-year is substantial. We should note that the 1964-68 total publications are not included in the 1964-68 computations. The data on scientist man-years are probably more accurate for the latter period. They are computed as the production-oriented scientist man-years (full-time equivalents) from Inventory of Agricultural Research, Research Program Development and Evaluation Staff, USDA, June 1967. The 1958-62 data, on the other hand, are not scaled into standardized units. Dairy science publications are included. In addition, the number of scientists is taken from the publication, "Workers in Subjects Pertaining to Agriculture in Land-Grant Colleges and Experiment Stations," Agriculture Handbook No. 116. These are not adjusted to full-time equivalent scientist man-years. For both sets of data, the matching up of scientists and publications is approximate.

The regional variations in scientist productivity are not necessarily related to the characteristics of the experiment stations, however. In Table 3 several comparisons between scientist productivity and station characteristics the data show that publications per SMY decline with the absolute size of the experiment station.

Correlations between publications per SMY and size of research staff are generally significantly positive. The same is true for the size of graduate program. The higher the percent of staff in branch stations, the lower is the average product or quality of research measured by publication. There is some evidence that the percentage of USDA personnel in the station is negatively correlated with crop research productivity.

These data deal only with pre-harvest agricultural research. They also do not include a comparison with USDA units in Beltsville and other locations. Furthermore, we cannot be sure whether the differences in quality are due to hiring practices or to the research environment provided to the scientists. (We attempt to address that issue in a later section).

Table 2: Scientific Publications by USDA Production Region

	Agricultural Publications Per Year		Publication per Scientist Man Year	
	1958-62	1964-68	1958-62	1964-68
1. Northeast	893	305	1.46	1.03
2. Lake States	719	197	2.47	1.04
3. Corn Belt	1021	300	1.98	1.00
4. N. Plains	299	138	1.18	.53
5. Appalachaia	431	171	1.42	.87
6. Southeast	340	196	1.43	.83
7. Delta	166	138	.86	.53
8. S. Plains	186	119	1.31	.50
9. Mountain	280	226	.84	1.01
10. Pacific	1096	342	1.81	1.14

Table 3: Productivity of Agricultural Scientists
Publications Per Scientist by Size Group

		By Size of Research Staff in 1963			By Size of Graduate Program 1958-62		
	Size Group	Crop Research 1958-62	Livestock Research 1958-62	All Agr. Research 1964-68	Crop Research 1958-62	Livestock Research 1958-62	All Agr. Research 1964-68
Smallest	I. 9 States	1.83	2.59	.99	1.96	3.10	1.05
	II. 10 States	1.55	2.10	.77	1.09	2.08	.75
	III. 10 States	1.23	1.90	.73	1.09	1.89	.78
Largest	IV. 19 States	.96	1.44	.71	.90	.89	.69

Note: Stations grouped by size in 1963 and by number of Ph.D's granted in the agricultural sciences 1958-62.

Correlations Computed from State Data

Average Product of	Research Staff 1962	Research Staff 1966	Graduate Program 1962	Percent of Staff in Branch Stations	Percent of Staff in USDA
Crop Res. 1958-62	.61		.58	-.06	-.04
Livestock Res. 1958-62	.42		.66	-.14	.02
Agr. Res. 1958-62	.61		.69	-.11	-.02
Crop. Res. 1964-68	.15	-.20	.23	-.30	-.46
Livestock Res. 1964-68	.34	-.00	.31	-.13	-.01
Agr. Res. 1964-68	.35	-.07	.39	-.31	-.36

III. The Concept of Research Quality: Economics Versus the Sciences

The organization of research programs and enterprises is quite specialized. This specialization is partially due to the incentive structure which determines the "appropriability" of research benefits by private individuals and firms and partially due to "real" gains from specialization along disciplinary lines. Associated with this specialization is a complex system of peer review standards by which quality is judged. These standards attempt to be consistent with efficiency, i.e., maximum output per unit of input within each specialization but are not necessarily consistent with efficiency of the entire system. Appplication of the standards of one level of specialization to another level also may be inconsistent with efficiency.

The general pattern of research specialization observed in what is here termed a system can be described by the following typology of research activities ranging from highly applied work (*) to work with little relationship to application (IV).

I. (Sub-Invention) Development (Engineering Refinement, Testing, etc.)
II. Mission-Oriented Invention or Technology Discovery
III. Applied or Mission-Disciplinary Research
IV. Scientific-Disciplinary Research

The central or core research activity in a particular system leading to new technology is invention process (II). Sub-invention or Development (I) is a natural extension of an invention and is made possible by invention. By and large, private individual and firm research activity is confined to types I and II. Some large private firms do establish some capacity to undertake type III research.

Public sector (including private universities and foundations) agencies engage in all four types of resarch. In general public research is concentrated in areas where exclusively private research would be inadequate or inferior.

Public research completely dominates scientific-disciplinary research (type IV), and plays a large role in applied-disciplinary research V (type III). This situation can be explained by the nature of the product. Type IV and type III research produces advances in knowledge which very often have the characteristics of "pure public goods." They cannot be sold in the open market, because "free riders" could make use of them without paying for them. (Advances in knowledge per se cannot be patented). Hence public funding of type III and IV research has an excellent economic rationale. (The arguments for public performance of the research are much less compelling; private research in this area could be incentivated by patents or prizes, or controlled by research contracts.*)

The recognition that small private firms have little incentive to engage in type II research is long-standing. The agricultural production sector of the economy is characterized by small farm firms. With a few notable exceptions in specialized products even the larger corporate firms in this sector have small market shares and generally confine their research-type activities to sub-invention except where patent protection may be acquired. Secrecy is precluded by the nature of most production inventions. The USDA and State Agricultural Research system has evolved to fill the need for production-oriented research of types II and III.

USDA researchers claim that an increasing portion of their resources is being allocated to problems raised by other government agencies in particular regulatory agencies. Since communications between organizations are neither perfect nor costless, there may be good reasons for conducting such "agency-servicing" research, which often appears to be of type I, within the public sector.

The USDA and State Agricultural Research Stations have been judged quite effective over the years according to recent studies.* As discussed above, the industrial structure of production agriculture is such that public sector research should be (at least potentially) particularly productive.

One of the principal reasons for its general success in realizing its potential is that it has developed a sensitivity to its main clientele -- the producing farmer. This sensitivity to clientele demand has influenced public sector agricultural research programs in two important ways. First it has provided an incentive structure to agricultural researchers to produce useful inventions (ii). Second, and perhaps more importantly, it has provided support for effective conduct of what we are calling "applied-disciplinary" or type III research. This type III research is crucial to the effectiveness of a research system because it is open to demand influence from the ultimate clientele of the system as expressed by type II researchers.

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*For further discussion of the choice between these alternatives, see Wright (1980b).

*See Evenson, Waggoner and Ruttan, 1979, for a discussion.

Post-harvest agricultural technology research is conducted primarily in the private sector. The firms in the relevant industries are often quite large and have incentives to undertake privately funded research programs. They can appropriate the gains from some of their research by taking advantage of their own market power and from others through patents. The public sector research programs are organized to provide some type III research of relevance to private firms and to engage in pilot and demonstration type II work.

It is important to note, however, that the real clientele supporting PHT research in the USDA and SAES are farmers and farm interest groups, rather than consumer groups or private business firms, though the latter may have an interest in a coalition with farm groups. Thus the orientation of public PHT research may differ from that conducted by the industry itself. Indeed the argument for public involvement in research in this particular area must rest largely on the contention that this difference in orientation leads to research that would not duplicate or replace private efforts. However, since the research output is not directly used by the dominant clientele, the feedback relationships which have proved beneficial in agricultural production research are probably less effective in PHT research.

The common standards for quality of research depend on the measurability of the output by the relevant clientele.

High quality type II research produces inventions or new technology, the value of which can be assessed directly by the clientele. In the private sector, some inventions are held in secrecy to enable the firm to capture increased profits. Others will be patented. In public sector agencies, inventions may be patented as well. Since patents are licensed without royalties, the patenting rationale rests on the value of disclosure. Many other discoveries will be reported in technical bulletins and other professional media. Patents are thus only a partial and very indirect measure of private sector evaluation of public type II research.

The standards for type IV research, on the other hand, are strictly determined by disciplinary "peer-review" processes, due to the difficulty of evaluation of output by others outside the research community. These peer-review standards tend to be influenced by a sense of usefulness, but on the whole, they reflect scientific opportunism. The peer-review system tends to reward contributions in a number of fields and encourage a broad range of studies. There is little question that disciplinary peer review systems and their associated journals encourage and direct the accumulation of scientific knowledge. Furthermore, they provide insights and a categorization of problems which is productive relative to mission-oriented guidelines.

The type III research programs may be seen as applying restricted or at least "weighted" peer review guidelines to research. The weights are derived from client pressure as expressed and articulated by type II researchers. Many applied or mission-oriented research institutions have real difficulty accomplishing an effective mix of type II and III research. "Tension" between applied and disciplinary interest characterizes all such institutions. Some deal with it more productively than others. When it is effectively handled, the output of type III research may be lower per unit of research input than type IV research when judged by type IV research weights. However, when type III weights are applied, this research can be seen to be very productive.

We noted earlier that economic quality standards could differ from scientific standards. Actually proper economic standards should fully recognize the productivity of scientific standards. An economically efficient system will include all of the specializating discussed here and there will be an optimal mix of the 4 types and optimal mixed economic and scientific weights for type III research.

The measurement of economic quality thus requires two types of analyses. First, for a given specialization, is optimum output being achieved given the resources at hand? Second, is a research system pursuing a proper mix of specializations?

With respect to the first question, we face the general problems of productivity measurement. Since direct research input is not the only determinate of research output and since there may be diminishing returns to direct research inputs, simple indexes of output (say inventions or even publications) per unit of input have to very carefully interpreted. We have a very substantial literature on returns to agricultural research now which suggests that the output/input ratio (or the rate of returns) is as high in the poorly developed research systems of the developing countries as it is in the more highly developed countries. Many observers find this difficult to believe in view of the apparent differences in the quality of research. It is, of course, a very simple matter to show that this evidence is consistent with lower quality research in the LDC's. Consider Figure 1 where the expected cost reductions (or other measures) are plotted against the research input measure for LDC's and developed countries (CDC's).

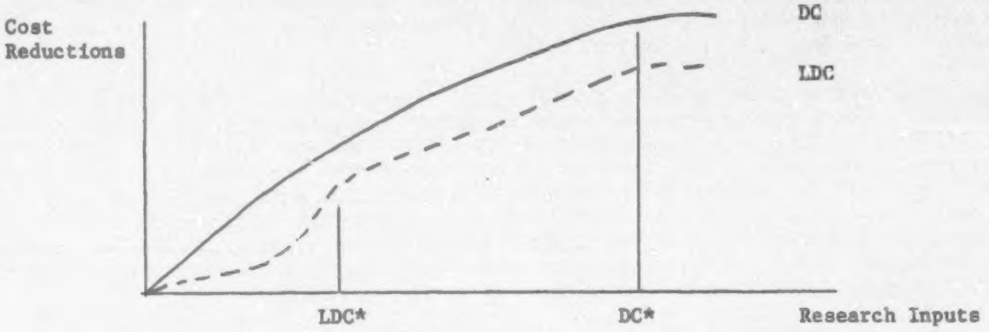

Figure 1

Figure 1

Note that at all levels of research inputs, the higher quality DC systems produce more cost reductions. However, because the DC's invest from 5 to 10 times as much as LDC's in research, they are subject to more diminishing returns and the marginal and average products of the low quality research may be higher.

This illustrates the importance of considering the level of research activity relative to other factor influencing productivity in assessing quality. Other factors include research results produced elsewhere which enhance local research productivity. Plant breeding materials and gene collections are examples.* Previous work of a more basic nature is another.

Even comparisons of the same research institutions of simple measures of research output (inventions, patented inventions, publications) per unit of input (scientist man-years, expenditures) are suspect. One cannot really tell whether a decline in output per unit of input is due to a decline in quality or to a decline in research potential as determined by other factors.

On the other hand, if one had enough data to estimate the counterpart of a production function (call it a patents function or a publication function), this problem could be addressed more directly. Suppose, for example, that we were assessing the quality of type II research and had a measure of output (patents or carefully screened publications) and inputs (SMY's). We would like also to have a measure of the stock of type III research discoveries which influence this research. Previous work on agricultural research shows type III research to be an important determinant of type II output per unit of inputs (see Evenson, 1975 and 1978).

The second issue regarding the optimal mix of specialties is more subtle because of the interaction between research objectives and standards and research productivity. This is due to the insights and guidance obtained from scientific standards. To illustrate, suppose that there are only 2 types of scientific discoveries S_1 and S_2. Figure 2 shows an expected transformation curve between increments to S_1 and S_2 from some given level of type IV resources. This transformation curve presumes that scientists are free to choose which of these stocks will contribute toward. They may move a point such as A.

Suppose another group of scientists (type III) is trained somewhat differently. They have disciplinary weights which limit their scope for discovery. This discipline, for example, may not impose the same measurement standards or the training may be "watered down" to some extent. Their transformation curve is as depicted. They do have the ability, however, to relate scientific discoveries to type II research and hence to judge the indirect economic value of ΔS_1 and ΔS_2. Again suppose it was the case that S_1 was of greater value than S_2. The type III researcher would then produce at b and be more productive and higher quality than type IV researcher.

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*In fact, there is a general hierarchy among experiment stations with central stations and branch stations. The latter are highly dependent on the former to be productive.

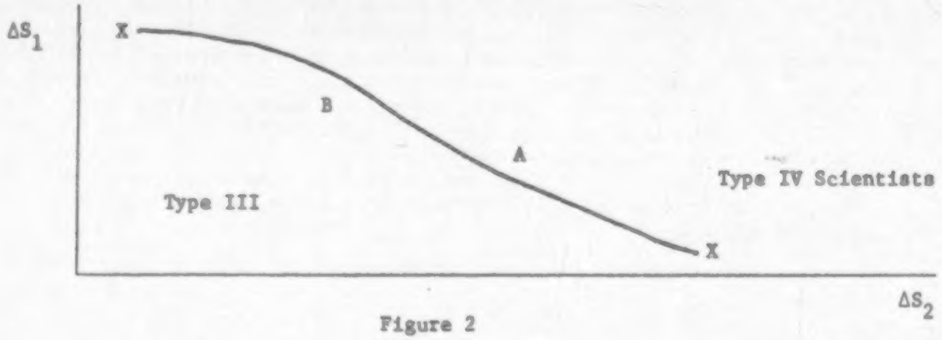

Figure 2

Figure 2 is intended only to be suggestive. In actuality, type III and IV researchers tend not to produce the same S_1's. Type III researchers often translate type IV research into more effective forms and their productivity thus depends on type IV research. Also type IV researchers are not impervious to the usefulness of their work and depend on type III research for guidance and suggestions. It is probably as inappropriate to apply type IV standards to type III work, although it is possible to compare certain research programs in this way (e.g., agricultural economics and economics). It is also the case that many type III researchers and institutions actually produce more type IV output than many type IV researchers and institutions. (Very often the claim of purity and theory orientation by academics is designed to camouflage incompetence).

We thus have two quality issues here. The first is whether research is measuring up to the standards set by its own specialization peer group. The second is whether the standards set by the specialization or disciplinary group are appropriate and consistent with broader research programs encompassing several research specializations. Indirectly, the second also encompasses the design and organization of the specializations as well. Ultimately, it may be possible to fully model this second set of questions. Ideally, if one had data on economic outcomes (production, prices, etc.) associated with alternative combinations of specializations and quality standards, one could identify the optimal mix.

We obviously cannot pursue this larger question here. We have, however, pursued two studies which, while limited in many respects, do address these quality concerns with some objective data. We view them as pilot studies which may provide a framework for more systematic work later. The first is a study of patenting output in PHT research. We believe this is important since an important part of research is designed to produce invention (type I). The second is a study of citations of type III PHT research.

IV. Patenting and Research Quality: A Pilot Study of USDA Post-Harvest Research

Patents provide a suggestive but imperfect measure of innovative activity and quality. There are at least two important problems with using patents as such a measure. First a patent does not necessarily represent a discrete step forward in the innovation process, nor is the extent of its contribution directly indicated by the patenting process. The "quality" of a patent, whether measured by the research behind it, the creativity of the invention, its economic value, or the clarity of its exposition (which are themselves difficult to measure) varies widely. The Patent and Trademark Office (PTO) does not make -- in fact, is forbidden to make -- any evaluation of the invention's contribution to the current stock of knowledge, beyond its judgment that the invention is original -- i.e., has not previously been patented.

The second problem with patents as a measure of innovation reflects the process of patenting itself. The cost of the patenting process, the "appropriability" of the returns from an invention, the prospects of litigation and incentives to patent vary over time, which means that the number of patents granted will fluctuate regardless of innovative activity. Also, the procedural attributes of a patent -- the number and kinds of claims allowed, the number and kind of patents an examiner cites in its examination may vary somewhat from examiner to examiner, from class to class, as well as from time to time as the PTO changes its directives. Thus, time series of patents cannot claim to hold all variables in the patenting process constant. For the above reasons, the evaluation of patenting activity over time must be interpreted as a broad study of trends rather than a precise analysis.

These qualifications having been made, one can set the present study of USDA patenting in a general context. During the 1970's the rate of patenting has fallen rather markedly in most sectors of the economy (see Table 4). This fall parallels the decrease in investment in research and development, both by private firms and by government agencies. (See Science Indicator, 1978). The exact relationship between these two trends, and between them and other trends such as the spread of government regulations, remains unclear and controversial. Although the current literature yields several theories and discussions of these trends, none of it pertains particularly to the USDA or other public agricultural research. Therefore, the patent study presented here begins with a discussion of the expected output of public research and its place within the general picture of U.S. patenting.

Table 4

Patents Granted Per Year by U.S. in Thousands

	1970	1971	1972	1973	1974	1975	1976	1977
To U.S. Inventors	47	55.5	52	52	51	47	45	42
To Foreign Inventors	17.5	22	23	22.5	25	25	25.5	24
Total	64.5	77.5	75	74.5	76	72	70.5	66

As discussed in Section III above, we might expect publicly directed research to be concentrated in areas where the expected market returns to private research are less than the expected social returns. If private researchers are risk-averse, then public research might also be advocated where the value of the outcome has a particularly high variance.

To the extent that this last rationale is important, the outcome of public research may be more variable. Relative to private resarch, it should contain more of a mixture of dead-ends and "breakthroughs", or seminal patents which induce and enable further private research. There is no sure method of calculating this, but two measures with some validity are the number of times a patent is subsequently cited by other patents and the number of licenses taken out on a given patent. One would expect the USDA to have a higher frequency of patents with zero citations or zero licenses than private patents, as well as a higher frequency of patents with a high number of citations and licenses.

Second, if one expects public research to tend to be more basic, its patents should occur early in a given sequence of patenting. There should also probably be a longer time lag involved in the citation of USDA patents, than of comparable private patents, as private industry adapts to and improves upon research which it did not originate.

Third, one might predict a high rate of USDA citation of its own patents, since its work, being more basic, and/or restricted to areas where private research is weak, is apt not to depend on private research as much as on its own. For this reason, also, one would predict that private patents would cite more foreign-origin patents than would those patents obtained by the USDA.

Attempts to test these hypotheses are complicated by the fact that the PTO, while certifying that a patent represents an original invention, does not provide a clear picture of the relation of the patented invention to those which have come before it or on which it is based. In the examination process, for example, the examiner cites several other patents which are in some way related to the patent under examination. The reasons for citing patents vary, however, and are sometimes contradictory. The examiner may cite a patent because it represents the "next best art," in which case the patent under examination represents an identifiable step forward. On the other hand, the examiner may cite a patent because it nullifies one of the claims which the patentee is attempting to make. In this case the cited patent is the superior or equivalent art. The examiner may simply cite a patent which is "of interest," with no clear relationship specified. There is substantial discretion on the examiner's part as to which patents and what types of patents he will cite. Also, the examiner has a strong incentive to cite those patents which set forth the prior art in a particularly clear and complete way, since he is less likely to have his judgment overturned if his patent is later contested. This cited patent, called a "teaching patent" because of its straightforward exposition of "disclosure," may in itself represent only a marginal advance in a given field. The breakthrough patent which preceded it is apt to be less clear and contain fewer obvious derivations because of the uncertain nature of the technology at the time it was invented. An examiner will, therefore, keep a ready stock of "teaching patents" on hand which serve the examination process well but which represent rather pedantic refinements of breakthrough patents. A "teaching patent" may be cited dozens of times over many years, whereas a breakthrough patent will be cited only until a "teaching patent" appears. For this reason, as well as those given above, patent citations do not lend themselves to precise interpretation.

Similarly, it is difficult to decide exactly where a "sequence" of patents begins and ends. This is particularly true in the absence of some knowledge of the art in question. The patent does not contain any information as to its impact or importance. For example, the patent lists the number of separate claims it makes after having described the invention or process which is being patented. There is virtually no relationship between the number of claims and the importance of the invention, however, Any invention may have several broad claims or many narrow claims. These claims may be of varying depth as well -- a "deep" claim meaning a major improvement and a "shallow" claim, a marginal one. Finally, private patents are usually prosecuted by patent lawyers who are paid according to the "breadth" of the claims they win, hence the private patent is apt initially to overclaim in an attempt to secure as broad a base for economic returns as possible. The USDA, not having this incentive, tends to claim much more narrowly and precisely, according to patent examiners. Its patents also tend to survive more or less intact through the prosecution of the patent, whereas private patents are negotiated to a much greater degree. One implication of this difference is that private patents, being broader on average, are more likely to serve as "teaching patents" and will be cited more often as a result.

The patenting process has come under fire in recent years for the comparatively lax examination process. For example, about 70% of all U.S. patent applications are granted (vs. 30% in the Federal Republic of Germany). Obviously, the more lax examination, the less valid is the granting of a patent as a research quality indicator. Further of all patents litigated, 70% are shown to be invalid (Germany, 41%). Since, in general, only private patents are litigated, there is no way of establishing the relative validity of USDA patents. Of course, most patents are not litigated.

Finally, the use of licenses as a proxy for the value of USDA patents is limited by the absence of a market determined price attached to a license; all USDA patents are licensed free of charge. Thus, there is no way to compare public and private licenses, especially since the price of a private license is usually proprietary information.

All of the above is set forth partly to emphasize that the study of patents is an inexact science. The data are presented here, not in an attempt to establish conclusively the quality of USDA innovation, but to give a rough comparison to private innovation and to demonstrate the results of trying to confirm some of the predictions listed above. As far as we know, most of the data we obtained, as difficult to interpret as it is, has never before been collected; apart from its value in this study, it should serve as a basis for further research.

By way of introduction to the following section, the table below shows the pattern of USDA patenting over two three-year sample periods, and gives a comparison with other major government agencies over the same period.

TABLE 4

PATENTS PER YEAR, MAJOR GOVERNMENT AGENCIES

Agency	1966	1967	1968	1977	1978	1979
USDA**	89	105	101	95	65	39
Air Force	115*	130*	165*	180	144	118
Army	320*	300*	305*	337	269	195
Atomic Energy Commission	270*	255	300*			
DOE/ERDA				40/156	191/4	163/0
HEW	26	20	11	25	32	18
Interior	50*	30*	50*	49	42	29
NASA	90*	100*	125*	104	101	119
Navy	495*	500*	470*	473	367	297

*Estimated

**As of August 20, the USDA had obtained 46 patents in 1980.

Our USDA patent data sample consists of all patents assigned to the USDA in two three-year groups, 1966-68 and 1977-79. They are summarized in Table 5. Each of these groups is divided into four categories: food, textiles and paper, unspecified chemistry, and other patents. Patents were assigned to the first two categories, food or textiles, on the basis of their being classified in a class and subclass which was occupied predominantly by food- or textile-related patents, or being cross-referenced to such a class, at the time they were issued. In a plurality of cases, the patent was classified and cross-referenced among various chemical classes and subclasses, and its title did not provide any clue as to its proper classification: some classes, such as liquid or gas separation, contained both food textile patents. In these instances, the patent was assigned to the third category, "unspecified chemistry." The final category consists of anything from soil samplers to harvesters; in general it was the smallest category.

TABLE 5

USDA Patents per year by Category (%)

	1966	1967	1968	1977	1978	1979
Food	19 (21.3)	24 (22.9)	24 (23.8)	12 (12.6)	11 (16.9)	8 (20.5)
Textiles and Related	27 (30.3)	33 (31.4)	42 (41.6)	23 (24.2)	21 (32.3)	7 (17.9)
Other Chem.	33 (37.1)	40 (38.1)	30 (29.7)	37 (38.9)	26 (40.0)	18 (46.2)
Other	10 (11.2)	8 (7.6)	5 (4.9)	23 (24.2)	7 (10.8)	6 (15.4)
Total	89	105	101	95	65	39

The data yield few smooth or unambiguous time series, partly because of the somewhat arbitrary classification system and partly because of the relatively small number of patents sampled each year. The most obvious trend, though, is the sharp decline in USDA patenting overall in the late 1970's, a trend mirrored in almost every other large government agency (See Table 4 above).

Citations per Patent

For the early sample, 1966-68, the number of patents cited by USDA food patents is about 2.5 each year; per textile patent, the average is about 3.2, with a high of 4.0 and a low of 2.9 (Table 6). In the later sample, the average per food patent is about 3.5; per textile patent, 4.6. One might infer that this trend to citing more patents indicates both the increasing sophistication of USDA patents in the area, as well as the larger number of "competitors" who are doing research similar to the USDA's (but see note below).*

TABLE 6

Average Number of U.S. Patents Cited
per USDA Patent, Food (textiles)

	1967	1968	1969	1977	1978	1979
	2.3 (4.0)	2.7 (3.1)	2.6 (2.9)	4.1 (3.9)	3.4 (5.0)	3.0 (5.4)
3-year Average		[2,57 (3.23)]			[3.55 (4.61)]	

As an example of this latter trend, the percentage of USDA patents which cite no other U.S. patent drops sharply in both areas from the earlier to the later sample. In food, nearly one-third of the USDA's 1966 patents did not cite any other U.S. patent, whereas this percentage dropped for the 77-79 sample to an average of one-eight. In textiles, where the USDA has historically had more competition, the average number of patents without U.S. citations was about 11% in the early sample, whereas by the later sample there wasn't a single USDA patent without at least one U.S. citation.**

TABLE 7

Distribution in Percent of Citations Per Patent, Food (Textiles)

Number of Patents Cited	1966	1967	1968	1977	1978	1979
0	31.6 (3.8)	25.0 (18.2)	16.7 (9.5)	8.3 (0.0)	9.1 (0.0)	25.0 (0.0)
1	15.8(11.5)	16.7 (15.2)	12.5(16.7)	18.3(17.4)	9.1 (0.0)	12.5 (0.0)
2	21.1(15.4)	20.8 (9.1)	20.8(26.2)	16.7(17.4)	18.2(23.8)	25.0(28.6)
3	10.5(15.4)	12.5 (18.2)	16.7(19.0)	8.3(13.0)	27.3 (9.5)	0.0 (0.0)
4	5.3(15.4)	0.0 (6.1)	8.3 (7.1)	0.0(17.4)	0.0(23.8)	12.5 (0.0)
5	0.0(11.5)	8.3 (18.2)	8.3 (9.5)	33.3(21.7)	18.2(14.3)	0.0(28.3)
6	5.3(11.5)	4.2 (3.0)	4.2 (2.4)	16.7 (4.3)	9.1 (0.0)	0.0 (0.0)
7	0.0 (7.7)	4.2 (3.0)	8.3 (4.8)	10.0 (0.0)	9.1 (9.5)	12.5(14.3)
8	5.3 (3.8)	0.0 (0.0)	0.0 (2.4)	0.0 (0.0)	0.0 (4.8)	12.5 (0.0)
9	5.3 (3.8)	8.3 (3.0)	0.0 (0.0)	8.3 (0.0)	0.0 (9.5)	0.0(14.3)
10+	0.0 (0.0)	0.0 (3.0)	0.0 (2.4)	0.0 (8.7)	0.0 (4.8)	0.0(14.3)
Total	100.0 100.0	100.0 100.0	100.0 100.0	100.0 100.0	100.0 100.0	100,0 100.0

Another suggestive exercise is to determine the percentage of USDA patents which cite zero private U.S. patents. This removes all USDA patents which cite only other USDA patents, and places them in the "zero citations" row.

From Table 7

Zero U.S. Citations Food (Textiles)

1966	1967	1968	1977	1978	1979
31.6(3.8)	25.0(18.2)	16.7(9.5)	8.3(0.0)	9.1(0.0)	25.0(0.0)

Zero Private U.S. Citations Food (Textiles)

36.8(14.8)	25.0(30.3)	29.2(19.0)	16.7(17.4)	9.1(0.0)	25.0(0.0)

This exercise suggests that espcially in the 1960's and especially in textiles, the USDA was dependent on its own research.

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*Appendix 2 details the means by which USDA and private patents were collected, classified & tabulated.

**According to one examiner, this trend could be explained partly by a directive issued by the PTO that all patents cite something, either another patent or journal article in its examination. Apparently, this directive was issued some time between the two periods covered in the sample.

Citation of Foreign Patents

Foreign patents may be divided into two categories: those granted by a foreign country, and those granted in the U.S. to a foreign inventor. USDA patents cited more foreign patents and foreign-invented U.S. patents in the later sample than in the earlier one. The citation of foreign patents actually fell from the first period to the second (Table 8, line 6), but this was more than offset by the increased citation of U.S. patents with foreign inventors (Table 9, line 6). The percentage of USDA patents in the early sample which cited neither foreign patents nor foreign-invented U.S. patents was 68.7 and 53.5 for food and textiles, respectively; in the later group, these percentages had each dropped 20 points (Table 10, line 10). Another measurement of foreign citation, average number of foreign patents cited per patent, shows that about twice as many foreign patents or foreign-invented U.S. patents are cited in the later group as in the earlier one (Table 10, line 9).

TABLE 8

Distribution in Percent of Foreign Patents Cited per USDA Patent,
Food (Textiles)

	1968	1967	1968	1977	1978	1979
0	94.7(61.5)	87.5(75.8)	83.3(85.7)	83.3(78.3)	81.8(95.2)	87.5(85.7)
1	0.0(19.2	4.2(18.2)	12.5 (4.8)	16.7 (4.3)	18.2 (4.8)	12.5 (0.0)
2	5.3(11.5)	4.2 (6.1)	4.2 (2.4)	0.0(13.0)	0.0 (0.0)	0.0(14.3)
3+	0.0 (7.7)	4.2 (0.0)	0.0 (7.1)	0.0 (4.3)	0.0 (0.0)	0.0 (0.0)
Average No. of Foreign Patents Cited per USDA Patent						
	.11(.65)	.25(.30)	.21(.45)	.17(.57)	.18(.05)	.13(.14)
3-Year Average						
		[.19 (.46)]			[.16(.31)]	

TABLE 9

Distribution of Percent of U.S. Patents by Foreign Inventors Cited
Per USDA Patent Food (Textiles)

	1966	1967	1968	1977	1978	1979
0	84.2(61.5)	58.3(63.6)	79.2(71.4)	75.0(52.2)	54.5(28.6)	50.0(57.1)
1	15.8(15.4)	37.5(33.3)	8.3(19.0)	8.3(13.0)	9.1(42.9)	37.5 (0.0)
2	0.0(15.4)	4.2 (3.0)	12.5 (7.1)	8.3(17.4)	18.2(14.3)	0.0(42.8)
3+	0.0 (7.7)	0.0 (0.0)	0.0 (2.4)	8.3(17.4)	18.2(14.3)	12.5 (0.0)
Average No. of Foreign-Origin U.S. Patents per USDA Patent						
	.16(.69)	.46(.39)	.33(.40)	.58(1.13)	1.08(1.19)	.88(.86)
3-Year Average						
		[.33(.48)]			[.87(1.11)]	

TABLE 10

Distribution in Percent of Foreign or Foreign-Origin Patents Cited
per USDA Patent, Food (Textiles)

	1966	1967	1968	1977	1978	1979
0	78.9(38.5)	54.2(54.5)	75.0(61.9)	58.3(34.8)	36.4(28.6)	50.9(42.9)
1	15.8(30.8)	33.3(30.3)	8.3(21.4)	25.0(17.4)	27.3(38.1)	25.0 (0.0)
2	5.3(11.5)	8.3 (6.1)	12.5 (9.5)	8.3(26.1)	18.2(19.0)	12.5 (7.1)
3	0.0 (7.7)	0.0 (9.1)	4.2 (0.0)	0.0 (8.7)	9.1 (9.5)	0.0 (0.0)
4	0.0 (3.8)	4.2 (0.0)	0.0 (4.8)	8.3 (4.3)	0.0 (4.8)	12.5 (0.0)
5	0.0 (3.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	9.1 (0.0)	0.0 (0.0)
6+	0.0 (3.8)	0.0 (0.0)	0.0 (2.4)	0.0 (8.7)	0.0 (0.0)	0.0 (0.0)

Average Foreign or Foreign-Origin Patents Cited per USDA Patent

	(1966)	(1967)	(1968)	(1977)	(1978)	(1979)
	.26 (1.35)	.67 (.70)	.45 (.79)	.75 (1.70)	1.36 (1.24)	1.00 (1.14)
3-Year Average		[.51 (.90)]			[1.03 (1.43)]	
3-Year Average of Patents with Zero Foreign Citations (from line 1)		[68.7 (53.5)]			[43.4 (33.3)]	

USDA's Use of Own Patents

TABLE 11

Percent of USDA Patents Citing One or More USDA Patents, Food, (Textiles)

	1966	1967	1968	1977	1978	1979
	21.1 (31.6)	16.7 (36.4)	45.8 (54.8)	58.3 (60.0)	18.2 (57.1)	25.0 (28.6)
3-Year Average		[28.3 (43.6)]			[35.5 (54.9)]	

As Table 11, line 2 shows, the number of USDA patents which cite previous USDA patents rose from the earlier to the later group, although the number of USDA patents cited as a percentage of all U.S.-invented patents cited actually fell for textiles (Table 12, line 2).

TABLE 12

Among USDA Patents, USDA Citations as a Percent of all U.S. Citations, Food (Textiles)

	1966	1967	1968	1977	1978	1979
	14.6 (22.4)	7.1 (29.5)	27.3 (41.0)	18.9 (35.9)	18.8 (22.5)	35.3 (14.3)
3-year Average		[16.4 (31.7)]			[19.0 (25.8)]	

Subsequent Citation of USDA Patents

Table 13, lines 1-4, show the frequency with which USDA patents were subsequently cited. The evidence is somewhat contradictory, in that food and textile patents seem to decline from 1966 to 1968; conversely, both "other chemicals" and "other patents" increase in frequency of citation, despite the fact that, of two patents with comparable "citability," the more recent should be cited less. Thus, one hypothesis which would explain the rise in citation frequency is that USDA patents became more "citable," hence perhaps more valuable. Alternatively, the areas of research in which the USDA obtained patents could have become more competitive, and more firms could be obtaining patents which differ only marginally from USDA patents, and therefore would cite them. Without knowing who cited the USDA patents, though, it is impossible to tell whether the patents in this sample were competing with private firms in the same areas or serving as bases for further USDA

TABLE 13

Average Number of Times USDA Patents were Cited Subsequently

	1966	1967	1968	1977	1978	1979
Food	3.3	1.96	1.83	(TOO RECENT TO FORM A VALID SAMPLE)		
Textiles	2.6	1.48	2.45			
Other Chemicals	1.33	1.8	2.27			
Other	1.8	2.88	3.0			

research and were subsequently cited by other USDA patents. A complete time series of all citations from 1966-79 would be the only way to determine this answer conclusively. That could be done by subtracting every instance in which a post-1968 USDA patent cited a patent in the 1966-68 sample, and inferring that the remaining citations of 1966-68 patents had come from private industry. The present evidence (Table 11) indicates that the USDA is more likely in the later sample to cite its own work than it was in the 1960's.

One difficulty with using patent citations to measure quality is that a patent may not be cited either because it is irrelevant and no one chooses to "build on" it, or because it is very good and no one is able to improve on it. One way to differentiate these two effects might be to use the number of patents cited by the patent in question as an index of similarity; a patent which cited no other patents and which itself is not subsequently cited appears to be rather isolated. It could represent a novel approach (citing no other patents) than no one subsequently improved upon (not subsequently cited). Still, after a period of 11-13 years this is unlikely, especially if either the USDA or private industry has on on-going concern in that patents area.

In any case, the number of patents with zero subsequent citations averages about 22% per year in the food area, compared with about 35% in the textile area and 40% in other chemicals. (Table 10).

TABLE 14

Percent of USDA Patents which have Zero Subsequent Citations

	1966	1967	1968	3-Year Average
Food	26.3	33.3	8.3	22.0
Textiles	34.6	42.4	28.6	34.7
Other Chem.	30.3	45.0	43.3	39.8
Other	30.0	37.5	0.0	26.1

Licensing of USDA Patents

Data of licensing of USDA patents were obtained from USDA's Office of Patents and Agreements. The majority of USDA patents are never licensed and of those licensed, the majority have only one license. Since it costs nothing to obtain a license for a USDA patent, it is difficult to give an economic interpretation to the following data except to treat the number of licenses granted as an index of interest in the patent. For this sample, licensing data are averaged for the three years covered by each of the two sample periods.

TABLE 15

Distribution in Percent of Licenses Per Patent

	66-68	77-79
0	90.5	87.4
1	5.4	8.5
2	0.3	1.5
3+	3.7	2.5
Total Licenses Granted	161	50
Average Licenses per Patent	.55	.25
Licenses Granted to 3 Most Licensed Patents as a Percent of all Licenses Granted	66%	42%

The data show that a small fraction of the USDA's patents account for the majority of the licenses it issues. One cannot compare the two sample periods directly because the more recent patents will necessarily have had less opportunity for licensing. One might note, however, that the percent of patents with at least one license is already higher in the later sample than in the earlier one. It is clear, therefore, that if one were to correct each sample for the difference in ages the more recent sample would prove to be more productive in terms of the percent of patents with licenses.

Private Patents*

For comparison purposes, a sample of private patents similar to those obtained by the USDA was collected for the years 1975-79. This sample covered food and textile patents, and was divided into U.S. and foreign inventors. (In the discussion that follows, Table 5* parallels Table 5, etc.)

TABLE 5*

Sample of Private Patents, 1975-79

	U.S.	Foreign
Food	48	30
Textiles	32	31

The data show a somewhat higher average of citations per patent among private firms than the USDA with virtually all of the per private patents having at least one U.S. citation (140/141). This may indicate the overlap in research is greater among private firms than it is between private firms and the USDA, as predicted.

TABLE 6*

Average U.S. Citations per Private Patent, Food (Textiles)

U.S.		Foreign	
4.7	(5.4)	48	(3.8)

TABLE 7*

Distribution in Percent of U.S. Patents Cited for Private Patent, Food (Textiles)

	U.S.		Foreign	
0	0.0	(0.0)	0.0	(3.2)
1	6.3	(0.0)	6.7	(3.2)
2	22.9	(25.0)	30.0	(12.9)
3	18.8	(9.4)	16.7	(9.7)
4	8.3	(12.5)	16.7	(9.7)
5	8.3	(18.8)	13.3	(16.1)
6	6.3	(12.5)	3.3	(6.5)
7	10.4	(12.5)	6.7	(6.5)
8	0.0	(3.1)	0.0	(6.5)
9	10.4	(3.1)	6.7	(6.5)
10+	8.3	(3.1)	0.0	(9.7)
Total	100.0	100.0	100.0	100.0

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*See Appendix 2 which details the means by which USDA and private patents were collected, classified, and tabulated.

Citation of Foreign Patents

TABLE 8*

Distribution in Percent of Foreign Patents Cited per Private Patent, Food (Textiles)

	U.S.	Foreign
0	77.1 (71.9)	73.3 (64.5)
1	18.8 (15.6)	20.0 (22.6)
2	4.2 (9.4)	6.7 (3.2)
3+	0.0 (3.2)	0.0 (9.7)
Averate number of foreign patents cited per private patent	.27 (.47)	.33 (.77)

TABLE 9*

Distribution in Percent of Foreign-Origin U.S. Patents Cited per Private Patent, Food (Textile)

	U.S.	Foreign
0	62.5 (43.8)	23.3 (19.4)
1	18.8 (37.5)	33.3 (19.4)
2	16.7 (9.4)	30.0 (19.4)
3+	2.1 (9.4)	20.0 (41.9)
Average number of foreign-origin U.S. patents per private patent	.60 (.88)	1.87 (2.8)

TABLE 10*

Distribution in Percent of Foreign-Origin U.S. Patents Cited per Private Patent, Food (Textiles) (Tables 4b and 5b Combined)

	U.S.	Foreign
0	45.8 (34.4)	23.3 (12.9)
1	29.2 (21.9)	26.7 (19.4)
2	20.8 (28.1)	10.0 (12.9)
3	0.0 (9.7)	20.0 (12.9)
4	4.2 (3.1)	13.3 (16.1)
5	0.0 (3.1)	6.7 (3.1)
6+	0.0 (0.0)	0.0 (22.6)
Average number of foreign or foreign-origin U.S. patents cited per private patent average percent of patents with zero foreign or foreign-origin U.S. patents cited (from line 1, Table 6b)	.86 (1.34)	1.93 (3.58)
	45.8 (34.3)	23.3 (12.9)

Tables 8* - 10* show the frequency of citation of foreign patents by U.S. and foreign firms. U.S. firms tend to make slightly less use of foreign patents than does the USDA, opposite to what one would predict.

Citation of USDA Patents

Table 11* and 12* show the frequency with which private firms cite USDA patents.

TABLE 11*

Percent of Private Patents Citing One or More USDA Patents, Food (Textiles)

U.S.	Foreign
18.0 (21.9)	3.3 (12.9)

TABLE 12*

Among Private Patents, USDA Citations as a Percent of all U.S. Patents Cited, Food (Textiles)

U.S.	Foreign
7.0 (8.2)	3.4 (6.3)

Table 11* shows that private U.S. firms cited USDA patents about one-fifth of the time, although Table 12* shows that the USDA's share of total U.S. citations was seven to eight percent. These statistics do not mean anything by themselves, because the frequency with which private firms cite USDA patents depends on how similar the patents in the private sample are to the USDA patents. Given that the private food and textile samples correspond to their counterpart USDA patents to about the same degree, though, the data indicate that both USDA food and USDA textile patents have roughly the same amount of "citability" as far as private firms are concerned.

Subsequent Citation of Private Patents

A second sample of private patents, covering the years 1966-68, was collected to compare the frequency of subsequent citation. In this sample, no distinction was made between U.S. and foreign patents. The sample shows that private firms tended to have their patents cited more frequently than the USDA's (Table 13*) and to produce fewer patents which were never cited subsequently (Table 14*).

TABLE 13*

Average Number of Times Subsequently Cited

	1966	1967	1968
Food	2.27	2.29	2.62
Textiles	3.00	3.65	3.68

TABLE 14*

Percent of Patents Having Zero Subsequent Citations

	1966	1967	1968	3-Year Average
Food	20.0	29.2	38.1	30.0
Textiles	16.7	25.8	14.6	18.8

The average percentage of food patents never cited subsequently is higher for private patents than for the USDA, and the average percentage of textile patents is lower.

One cannot draw precise information from these data, except to say that there is no evidence that the USDA produces an unduly high number of "dead end" or uncitable patents relative to private industry.

In general, these data, while indicating a decline in USDA patenting over the 1966-79 period, also suggest that some possible improvement in the quality of the patents may have occurred.

V. Publications and Citations as Quality Indicators

The larger part of public PHT research is probably type III research which, of course, does not lead to patented inventions. It is designed to provide research potential which in turn leads to inventions and technology. As with public PHT research, it is probably oriented toward technology areas which the private sector does not see as currently highly viable.

One of the measures of output of this type III work is the publication. With data on publications which have been subject to quality screening, one could undertake analysis of differential productivity in different research environments and in different time periods. It is difficult to obtain good data on quality screened publications, however. Publication data reported in data files such as AGRICOLA or the USDA CRIS system are not generally standardized for quality.*

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*Appendix A provides a discussion of data bases and a number of problems encountered with them.

We concluded after an initial investigation that citations of publications were of a superior measure. The number of citations on index of the "importance" of a research contribution.

Perhaps more importantly, citation data can tell us something about the usefulness of one research specialization (or location, or institution) to other research specializations. Thus, if public PHT research publications are subsequently cited only by public PHT researchers, this would be cause for concern. Citation analysis has been used very little to date in agricultural research evaluation. We view our effort as something of a pilot effort to learn something from these data.

Experimental Station (SAES) Publications:

To obtain a better measure of quality-adjusted publication output, we decided to count citations in major journals of articles published. Using Science Citation Abstracts (SCA), and a list of researchers, an entry was made for each of the articles by one of these researchers as major author which was cited by one of the journals from a list containing four categories: (1) Food, (2) Agricultural, (3) Materials Science (textiles and wood) and (4) Other. The first three categories were constructed from all the journals in these areas cited by SCA in both 1967 and 1979.* The fourth category, "Other," was constructed from the 48 journals which had the greatest number of citations of a list of USDA regional research center authors. The journals used are shown in Appendix 3.

This procedure was used to construct two data bases designed to present information on research quality:

Data Set A:

This data set contains comparative data on research inputs and outputs for State Agricultural Experiment Stations (SAES) USDA Regional Research Centers (RRC), and six other smaller USDA area laboratories (AL). To concentrate on areas which come under the heading of post-harvesting technology (PHT), we gathered published CRIS input data for three Research Problem Areas (RPA's):

#403 New and Improved Fruit and Vegetable Products
#406 New and Improved Fruit Products from Field Crops
#407 New and Improved Feed, Textile and Industrial Products from Field Crops

The input data include funding by source--Agricultural Research Service (ARS), SAES (including other state-origin funds), and Cooperative State Research Service (CSRS) funds. The commitment of personnel is also included by scientist man-year (SMY) for each research location; unfortunately, no distinction of SMY's by source of funds is requested in the USDA questionnaires used to collect the raw data.

To evaluate research performance in the chosen RPA's, output data much be related to the RPA's. Apparently no data source exists which provides a comprehensive list of publications by project on RPA. Nor is there publicly available a list of all researchers by project in each RPA.

In the face of these difficulties, we were forced to resort to a study of the research performance of the principal investigators as an indicator of the productivity of their research projects. As described in Appendix 1, the computerized CRIS file was used to provide a list of the names of principal investigators by project. (This was, in fact, the only significant contribution which could be furnished by the available computerized data sets.)

These names were then searched in SCA 1979 and each citation of an article by one of the journals in the designated list was classified as described above. This data set is used in a pilot study of the relative productivity of SAES, RRC, and SAL research, as reported below.

Data Set B:

The second data set concentrates on the comparison of the productivity of Regional Research Center (RRC) research output between stations and over time. The RRC's are of particular interest as they dominate the public PHT research arena in the United States, in terms of SMY's, funding, and citing publications.

This data set contains the same type of citation information used to build Data Set A. But in this case the population of researchers is chosen in a more comprehensive fashion. To come as close as possible to a complete list of publishing research personnel at each of the four centers, citations were obtained for each person who authored or co-authored any article appearing in the List of Publications and Patents for respective centers. The list chosen were for the year 1978 and 1966, for the Northern, Southern, Eastern and Western RRC's.* However, despite several direct telephone contacts and a search at the National Agricultural Library, the Southern list for 1966 could not be located. The citations data were obtained from SCA 1979 and 1967, and classified exactly as described in Data Set A; in fact, some economy of effort was derived from the overlapping of the two data sets.

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*Not all these journals correspond with the SCA subject categories for both years. For example, in our list Soil Science Journals were always included under Agriculture.

This data set contains an enormously rich fund of information on the productivity of RRC researchers over time, and on the time-related "citation profile" of their articles in prominent journals. At this state, time and budgetary limits have precluded computer analysis of Data Set B. However, even a simple tabulation, as presented in Table 16 contains some useful information.

TABLE 16

Citations of Regional Research Center Personnel

	Year of Citation in Designated Journal List	
	1966	1978
Northern RRC		
Number of Citations[1]	590	1075
Number of Researchers[2]	184	218
Citations/Researcher	3.21	4.93
Southern RRC		
Number of Citations		544
Number of Researchers	(na)	185
Citations/Researcher		2.79
Eastern RRC		
Number of Citations	912	521
Number of Researchers	268	151
Citations/Researcher	3.40	3.23
Western RRC		
Number of Citations	1564	823
Number of Researchers	356	162
Citations/Researcher	4.39	5.08
Total		

[1] Citations in a separate article by a person other than the cited author in a journal in the list described in the text.

[2] To guard against counting non-research employees (administrators, laborers, extension workers, etc.), whom we found difficult to distinguish in available personnel lists, only researchers who authored or co-authored a publication in the List of Publications and Patents for the relevant year and RRC were counted, and searched in SCA.

The citation data do not, of course, represent research output in the year of citation. Some citations come from very old articles which are generally of superior quality and have been cited in several earlier years. But the data indicated that the typical citation profile of an article peaks within the first half-decade, so the data largely reflect fairly recent publishing efforts.

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*The list of authors included all authors listed as major or minor authors in Northern, Southern, Eastern and Western Regional Research Center List of Publications and Patents for the years 1966 and 1978. Restrictions of the field of citation helped greatly in reducing errors from counting citations due to other authors of the same name.

The four Regional Research Centers are the Northern (Peoria, Ill.), Southern (New Orleans, La.), Eastern (Philadelphia, Pa.) and Western (Berkeley, Calif.).

Few of the 1966 researchers appear on the 1978 lists. However, those that do tend to be quite prolific and tend to have some old article cited in 1978. Thus the intertemporal comparisons may, to some extent, be biased in favor of higher average productivity of the later year. However, this would not be true if the proportion of these older high-productivity personnel, and their citation characteristics, do not change over time.

The citations reported in Table 6 are, of course, pre-screened by the research peers who referee for the journals in our list. Based on Table 16 we can make the following observations:

(1) The figures contain no evidence of any significant decrease in high-quality research output per researcher over the time span we considered.

(2) Researchers at the Western RRC appear to be somewhat more productive of citations than those at the Northern and Eastern centers in both years.

(3) Researchers at the Southern RRC show the weakest performance in terms of citation productivity. (However, as we see above, this RRC shows the strongest performance in patenting).

2. The Productivity of PHT Research by Location

Data Set A, discussed above, contains information on citations by principal investigators of projects in three PHT-dominated RPA's (numbers 403, 406, 407), and on research inputs into those RPA's. We used this data set to test the effect of research location on the productivity of principal investigators.

It is not reasonable to expect that the principal investigator will be the major author on all papers produced in his research project. However, we hypothesize that the number of scientist man-years (SMY's) and the fund-intensity of each man-year (FDSY), will affect the number of citations production function as TC79 = f (SMY, FDSY, NPI, STA2, STA3), where TC79 is citations in SCA 1979 of articles from 1977 to 1979, by principal investigators in the three PHT RPA's at a given location.

SMY is scientist man-years in those RPA's, and FDSY is funds per SMY, a measure of the resource intensity per scientist. NPI is the number of principal investigators per location in the three RPA's. STA2 and STA3 are dummies for the four regional research centers (RRC's) and the other USDA area laboratories, (ALR), respectively.

After dropping observations with zero SMY, zero funding or zero NPI, we obtained a sample of 54 observations, including 4 SEA's, 4 RRC's and 6 AL's.

To test the above specification of the citations production function, the following OLS regression was obtained (standard errors are in parentheses).

$$\begin{aligned} TC79 = \underset{(4.27)}{2.99} + \underset{(0.200)}{0.750}\ SMY + \underset{(0.0432)}{0.00915}\ FDSY \\ + \underset{(0.200)}{0.469}\ NPI - \underset{(10.3)}{9.32}\ STA2 - \underset{(4.33)}{3.26}\ STA3 \end{aligned}$$

$$R^2 = 0.792$$

The coefficients of SMY and NPI are highly significant, but none of the others is even weakly significant.

The dummies STA2 and STA3 are of particular interest, as they represent the independent "station type effect." Since both coefficients are insignificant, this regression does not refute the hypothesis that both types of USDA institutions (RRC's and AL's) are as efficient as SAES's in turning out quality research from their respective principal investigators.

However, the above regression ignores differences in the quality of the principal investigators. The failure to detect a station type effect could be consistent with a situation where there is a significant difference between the productivity of two types of station holding quality principal investigators contstant, but this is compensated by the hiring of more highly productive principal investigators, in the stations with a negative station type effect on output.

To control for the quality of principal investigators, we decided to include a measure of their previous professional output, controlling for quality the chosen measure in an aggregate of past citations. To avoid undue bias against younger principal investigators, the period chosen must be fairly recent. But to minimize contamination by current projects, the period should end before current projects were initiated. As a compromise we chose TC04, total citations from the designated set of journals in 1979 of articles published from 1970 through 1974, for all principal investigators in the relevant RPA's at a given location.

When TC04 was included in the regression, we obtained the following results:

Table 17: Analysis of Publications by PHT Researchers

```
                                   SSE      1754.78         F RATIO          3.41
                                   DFE          438         PROB>F         0.0001
DEP VAR: A69                       MSE     4.006347         R-SQUARE       0.1100

                             PARAMETER     STANDARD
VARIABLE          DF          ESTIMATE        ERROR         T RATIO     PROB>|T|

INTERCEPT          1          1.862053     0.563465          3.3046       0.0010
L2                 1          0.540455     0.555422          0.9730       0.3311
L3                 1          0.517824     1.137251          0.4553       0.6491
L4                 1          0.221178     0.885450          0.2496       0.8029
L5                 1         -0.181276     1.057748         -0.1714       0.8640
L6                 1         -0.512065     1.094654         -0.4678       0.6402
RP1                1         -0.377119     0.370502         -1.0179       0.3093
RP2                1         -0.712393     0.330353         -2.1565       0.0316
RP3                1         -0.237877     0.338470         -0.7028       0.4825
AGE                1         -0.042724     0.046028         -0.9282       0.3538
AGE2               1      0.0001679716  0.001236289          0.1359       0.8920
F1                 1          0.228395     0.762537          0.2995       0.7647
F2                 1          0.146956     0.373721          0.3934       0.6942
CE                 1          0.073559     0.011869          6.2256       0.0001
DE                 1          0.239652     0.295136          0.8038       0.4219
SMY                1       0.000362384  0.001691666          0.2142       0.8305
FDSY               1      0.0006676899  0.003231695          0.2063       0.8366

                                   SSE     4965.671         F RATIO          5.82
                                   DFE          437         PROB>F         0.0001
DEP VAR: C69                       MSE    11.400657         R-SQUARE       0.1347

                             PARAMETER     STANDARD
VARIABLE          DF          ESTIMATE        ERROR         T RATIO     PROB>|T|

INTERCEPT          1          2.358192     0.985135          2.3938       0.0171
L2                 1          1.077890     0.964207          1.1179       0.2642
L3                 1          1.350405     1.922787          0.7023       0.4829
L4                 1          0.965546     1.498446          0.6452       0.5191
L5                 1          0.741743     1.784979          0.4155       0.6779
L6                 1         -0.161754     1.847242         -0.0876       0.9303
RP1                1         -0.374576     0.268188         -1.3970       0.1629
RP2                1         -1.560750     0.557475         -2.7996       0.0053
RP3                1         -0.601170     0.571631         -1.0517       0.2935
AGE                1         -0.010324     0.077827         -0.1327       0.8945
AGE2               1      -0.000161739  0.000209553         -0.7718       0.4406
F1                 1         -0.223671     1.246824         -0.1794       0.8577
F2                 1          0.182657     0.633804          0.2882       0.7733
CE                 1          0.166592     0.020026          8.3175       0.0001
DE                 1          0.062677     0.503225          0.1246       0.9009
SMY                1       0.000905423  0.002891447          0.3132       0.7543
FDSY               1       0.003904995  0.005549716          0.7036       0.4820
NFSY               1          0.412932     0.495327          0.8337       0.4049

                                   SSE   125.083617         F RATIO          1.80
                                   DFE          243         PROB>F         0.0312
DEP VAR: C69A69                    MSE     0.514745         R-SQUARE       0.1062

                             PARAMETER     STANDARD
VARIABLE          DF          ESTIMATE        ERROR         T RATIO     PROB>|T|

INTERCEPT          1          1.444637     0.266234          5.4262       0.0001
L2                 1          0.052145     0.270587          0.1927       0.8473
L3                 1          0.405920     0.596291          0.6801       0.4971
L4                 1          0.368275     0.393922          0.9352       0.3501
L5                 1          0.843019     0.491796          1.7142       0.0876
L6                 1          0.644623     0.509790          1.2645       0.2073
RP1                1         -0.246083     0.179341         -1.3721       0.1713
RP2                1         -0.331141     0.157344         -2.1046       0.0363
RP3                1         -0.061807     0.163480         -0.3781       0.7057
AGE                1          0.030075     0.021846          1.3767       0.1699
AGE2               1      -0.000365515  0.000245626         -1.4881       0.1376
F1                 1         -0.297472     0.347170         -0.8568       0.3924
F2                 1         -0.040559     0.183220         -0.2214       0.8250
CE                 1      0.0096122506  0.004582592          2.0974       0.0370
DE                 1         -0.157231     0.154605         -1.0170       0.3101
SMY                1      -0.000544422  0.000804904         -0.6762       0.4995
FDSY               1      0.0001259982  0.001932196          0.0652       0.9321

                                   SSE    78.009620         F RATIO          2.61
                                   DFE          438         PROB>F         0.0007
DEP VAR: D69                       MSE     0.178105         R-SQUARE       0.0870

                             PARAMETER     STANDARD
VARIABLE          DF          ESTIMATE        ERROR         T RATIO     PROB>|T|

INTERCEPT          1          0.590275     0.118804          4.9685       0.0001
L2                 1          0.084592     0.117114          0.7223       0.4705
L3                 1         -0.010236     0.239764         -0.0427       0.9660
L4                 1          0.266622     0.186698          1.4281       0.1540
L5                 1          0.175542     0.223621          0.7871       0.4316
L6                 1          0.200416     0.230602          0.8683       0.3857
RP1                1         -0.017313     0.078116         -0.2216       0.8247
RP2                1         -0.036550     0.069653         -0.5247       0.6000
RP3                1          0.011964     0.071363          0.1677       0.8669
AGE                1         -0.044456  0.009704674         -4.5809       0.0001
AGE2               1      0.0006969255 0.0002230653          3.1181       0.0020
F1                 1          0.095151     0.168721          0.5640       0.5731
F2                 1          0.123701     0.078695          1.5719       0.1167
CE                 1       0.005307141  0.002501416          2.1217       0.0344
DE                 1          0.171137     0.062860          2.7225       0.0067
SMY                1     -0.0008634377 0.0004856667         -1.7797       0.0758
FDSY               1      0.0001676083 0.0006822722          0.2457       0.8061
```

$$\begin{aligned} TC79 = \underset{(3.62)}{2.65} + \underset{(0.199)}{0.606}\ SMY + \underset{(0.0366)}{0.00457}\ FDSY + \underset{(0.181)}{0.184}\ NPI \\ + \underset{(0.0547)}{0.244}\ TC04 - \underset{(8.75)}{4.50}\ STA2 - \underset{(3.68)}{1.78}\ STA3 \\ R^2 = 0.854 \end{aligned}$$

The station type dummies are once again insignificant, as is FDSY. TC04 has a highly significant coefficient, and the coefficient of NPI now becomes insignificant. This is a very interesting result, because it indicates that principal investigator inputs can be counted by aggregating their past citations; the number of individuals involved does not add significant additional information on future productivity. The elasticity of TC79 with respect to TC04 is 0.39.

3. Research Productivity and Research Quality by Individual Researcher

Data set A also lends itself to an analysis where the researcher is the unit of observation. For each principal investigator listed in the 3 RPA's, we have observations on the following variables:

Dependent Endogenous Variables

A69:	Number of articles published 1976-79 with at least one citation in CA
C69:	Number of citations of articles published 1976-79
C69A69:	Citations per article
D69:	Percentage of citations in journals classified in the same field as the field of publication

Independent Endogenous Variables

L2:	Dummy = 1 if ARS research outside 4 reg. labs
L3:	Dummy = 1 if ARS in Eastern Utilization Lab
L4:	Dummy = 1 if ARS in Western Utilization Lab
L5:	Dummy = 1 if ARS in Northern Utilization Lab
L6:	Dummy = 1 if ARS in Southern Utilization Lab
RP1:	Dummy = 1 if researcher works only in RPA = 407
RP2:	Dummy = 1 if researcher works only in RPA = 403
RP3:	Dummy = 1 if researcher works only in RPA = 406
AGE:	Years since publication of earliest paper cited in 1979
AGE2:	AGE squared
F1:	Dummy = 1 if funded by ARS
F2:	Dummy = 1 if funded by CSRS
CE:	Number of citations in 1979 of papers published before 1970
DE:	Defined as D69 for papers published before 1970
SMY:	Number of full time scientist man years in the RPA in the performing institution
FDSY:	Expenditures per SMY in the RPA in the performing institution

Table 17 reports 4 regressions, one for each dependent variable. It is important to note that A69 and C69 are measured on a per scientist basis. The C69A69 and D69 variables measure characteristics of the publication themselves. These are not comparable to the previous regressions where TC79 was measured in terms of citations for all publications produced in the 3 RPA's in the institutions where they work. Accordingly R-square measures are not comparable in any sense. Indeed we would expect very low R^2 for these regressions because of the forms of the dependent variable.

Regression 1 reports on analysis of cited publications per MSY.

We note that there is no evidence that the institution in which the research works affects his publication productivity (SAES locations are the left out group) and L2 - L6 are not significantly different. It appears that researchers with projects in RPA403 (and to some extent in the other single RPA's) produce fewer publications than researchers with projects in two or more RPA's (the left out group). It is clear that those researchers who have published earlier papers (pre-1970) which are now cited heavily are also producing more papers currently reflecting personal quality. Controlling for this variables such as age and the size of research unit in which the work is done do not have a significant effect. Funds per SMY in the unit in which they work also does not have a significant effect. (Dropping the CE variable does not change these conclusions).

Thus, this regression is consistent with the previous regression. There are personal differences in publication output per SMY but we do not find significant effects of institutional characteristics. In some sense finding that no significant institutional differences exist is as important from a policy perspective as finding that there are differences.

Regression 2 provides the same analysis of citations per SMY. The results are essentially the same as those discussed for regression 1. We find no significant institutional effects. (The astute reader will note that regression 2 is similar to the regression reported on page 5 and that if we were to simply aggregate our data for each institution and run old SMY's as a dependent variable we could arbitrarily achieve on R^2 or .8 or so).

Regression 3 reports an analysis of citations per publication. Since regressions 1 and 2 told us essentially the same story regarding publications and citations, we should not expect to learn anything from this regression, We don't learn very much.

Regression 4 is an attempt to see whether there are systematic factors influencing the diversity of citations. We noted earlier that it was important that publications produced by public sector PHT researchers be influential outside the narrow confines of the PHT fields. D69 measures the proportion of citations in journals classified in the same field as the publication. (See Appendix 3). Factors which reduce D69 presumably expand the influence base of this research.

As with the earlier measure, we find no institutional effects. We find that younger scientists have more influence outside their fields than older scientists and that scientists with high early productivity and narrow influence have narrower current influence.

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Appendix 1

Investigation of Computerized Research Data Bases

In our initial research agenda, we intended to make extensive use of the computerized research databases which have recently become available, in evaluating the quality of agricultural research. Unfortunately, our investigation of these research aids yielded largely negative results with respect to our pilot project (Section IV). However, these data sources are potentially very valuable in both in-house and external research evaluation. Our experience, reported below, should be useful in any future attempts to modify these databases so that they can be of maximum use in research evaluation.

On June 12-13, a research assistant associated with the project traveled to New York to attend a 1-1/2 day seminar on searching computer databases, offered by the DIALOG Information Retrieval Service, a division of Lockheed Missiles and Space Co. The cost of this seminar was $65, which seemed to be a justifiable expense, in view of the high cost of computer searching ($24 - $90/hr.) and the number of hours which were anticipated to be necessary (20-30); at these rates, it appeared likely that the expertise gained would more than pay for itself. Also, none of the facilities at Yale which perform computer searches were willing to devote such a large amount of time to one project. Finally, the seminar provided valuable free practice time.

The research assistant was subsequently able to experiment at length with several Government and private research databases, with the object of determining conclusively whether a systematic search would yield the necessary data. The first set of data sought was a complete list of all publications by each state agricultural experiment station (SAES), and USDA research laboratory from the years 1967-1980. This time period was determined by the availability of the so-called "CRIS data," which is a shorthand way of referring to the Inventory of Research published by the Current Research Information Systems, a section of the USDA's Science and Education Administration. The CRIS data contain information on the number of scientist man-years (SMYs) and state and federal expenditures spent at each SAES and USDA lab, broken down by research problem area (RPA), and by commodity. In this way, the researchers hoped to match output, in number of journal-quality publications, to input, SMY's and money, and to test for statistical significance. The researchers hoped to match output, in number of journal-quality publications, to input, SMY's and money, and to test for statistical significance. The researchers anticipated developing a similar function using subsequent citations of SAES and USDA papers as output, and a third function using patents as output. As it turned out, the most recent CRIS data published is for 1977.

In general, a computer search takes the form of imposing a set of conditions on the entries in a given database, and determining how many of those entries fit the conditions. In verbal form, one asks the computer, for example, "how many papers were published by the Maryland SAES in 1972 with the word "fruit" in the title or abstract?" If standardized answers were to result from this question, one could, with little time or expense, create a time series for each SAES and USDA lab of publications in a given area. With each database, however, there were different limitations on the extent to which one could separate "wheat from chaff," i.e., impose enough conditions to ensure a precise sample without having to examine the papers themselves, one-by-one.

For publications, databases pursued were Current Research Information Systems (CRIS), and AGRI Cultural On-line Access (AGRICOLA), both published by the USDA; Food and Science Technology Abstracts (FSTA), published by the International Food Information Service, Berkshire, U.D.; and FOODS ADLIBRA, a database covering the food industry. FOODS ADLIBRA was unsatisfactory because it did not list SAES or USDA publications. FSTA listed SAES and USDA publications, but it proved impossible to instruct the computer to "screen out" all those publications which came from universities affiliated with a SAES from publications coming from the SAES themselves, without examining the bibliographic entries on a one-by-one basis. Since several thousand publications fit this description, it was impractical to examine them one by one, also, any advantage to using the computer was lost. An even greater conceptual problem was that there was no sure way to assign a paper listed in FSTA to a given RPA and commodity simply on the basis of the words in its title or "description field," which is the means by which the computer searches. For example, if the CRIS data of 1977 indicated that the Maryland SAES spent X SMYs and Y dollars on RPA 403 (New and Improved Fruit and Vegetable Products), one would want to know how many papers resulted directly from those expenditures. There was no way to circumscribe the search in FSTA in a sufficiently precise way to guarantee an exact matchup of paper topics to an area of funding; input and output could not be translated into a common language.

This same problem plagued searches on the AGRICOLA database, which covers all USDA publications. A second problem was controlling the quality level of publications; AGRICOLA includes not only journal articles, which have passed some kind of peer review, but technical bulletins, public interest bulletins, masters' and doctoral theses, and other publications of unknown quality. These could not be screened out from the search, except by inspection, which again defeated the purpose of a computer search. Finally, for some reason the ability to search for papers published prior to 1979 is severely limited on AGRICOLA; for example, one cannot search by the name of the journal in which the publication appeared. All of these problems mean that "noise" is inevitably introduced in response to any set of conditions imposed by the searcher.

The CRIS database was the most comprehensive of the lot, and provided the unique advantage of being able to limit entries to a given RPA and commodity, which promised a much better matchup of input to output. The difficulty with CRIS is that an "entry" is not a publication but a project; CRIS was designed to allow researchers within the USDA-SAES umbrella to keep track of parallel research efforts currently being conducted in areas similar to their own. Ostensibly, each project is updated once a year, at which time a new progress report replaces the one on file, and a new set of publications, associated with the project, replaces the ones previously listed. In addition, projects are supposedly maintained on file two years after their termination date, and then "purged" from the database, leaving no historical record. For a variety of reasons, none of these procedures is carried out regularly. To the extent that they are carried out, however, they eliminate information, in the form of historical records, from the "current" file, and it is this information which is necessary to developing a time series.

The only foreseeable way to circumvent these problems would be to make use of past CRIS records, which are stored on tape at the main USDA computer in Washington. These tapes are not "on-line", however, but must be hand-loaded onto the computer, and searched via a batch-processing (pre-written program) rather than interactive format. Middle-level managers of CRIS indicated that, absent any overriding command, the department was unlikely to load these tapes for the sake of an outside research project such as OTA's; in any case, the time required would place the results long after OTA's first-draft deadline. Even if the department could be persuaded to operate the tapes, though, it appears that the CRIS format only permits five publications per year to be listed with any one project, which distorts the output of very productive projects, and these publications include masters' and doctoral theses, staff papers, and other publications lacking an independent evaluation.

Therefore, the conclusion that the researchers reached after repeated searches and discussions with CRIS people in Beltsville was that no satisfactory database existed which would allow anything other than an extremely crude matchup of input to output, not even anything so refined as limiting the problem to "post-harvest technology." Except for the bureaucratic problems noted with updating CRIS, the database appear to function well at what they are designed to do, which is to provide a searcher with a reasonably complete and pertinent list of publications or projects. For the purpose at hand, however, "reasonably" was not close enough.

In the case of the citation search, it proved to be much cheaper to employ a research assistant at $4.00/hour to search the Citation Abstracts than to use the comparable computer database at $90.00/hour. Virtually no time-saving aggregation could be accomplished on the computer, and the research assistant was able to obtain more detailed information on the type of journal in which the article appeared versus the type of journal in which it was cited ("type" refers to four categories: Food Science, Agriculture, Materials Science and Other).

The patents file was searchable for all information except the list of patents which an examiner cites in granting a given patent, which can only be obtained by looking up the given patent, and the number of times a given patent is subsequently cited, which is available at no charge from a private firm near the Patent and Trademark Office. If this information were not desired, it would be questionable whether it was cheaper to travel to Washington or to search by computer. Without this information, however, one loses almost all connection to the prior technology to which a given patent is related.

The one area in which the computer proved useful was in generating the names of chief project investigators at SAES and minor USDA labs according to the RPA in which they were conducting research. In this case the CRIS database functioned much like an expensive but very precise telephone directory. Once these names were obtained, research assistants went to the Citation Abstracts publications to look up each investigator's "citation history" manually. Because the researchers knew with certainty that these investigators worked in a specific RPA, they could match the citation output to the input listed in the CRIS data. The disadvantage of this approach, though, was that only the principle investigator's name is associated with a project, which means that the citation histories of junior faculty and staff could not be investigated.

Appendix 2

Collection of Patent Data

Detailed data were obtained for patents in the food and textile categories. These data include the date of application (which ranges from 1-6 years prior to data of issuance), the state of origin, and the number of the patent's claims; the number of cited patents and their state or country of origin; the number of claims for each cited patent; and, if they were obtained by a major U.S. or multinational corporation, which one. Each USDA patent, including those in the "unspecified chemistry" and "other" categories, was also checked to see how many times it had been cited by another patent since its data of issuance.

For the private firm sample, detailed data were obtained for patents in the food and textile categories for post-1975 patents only. These patents were matched to comparable USDA patents by taking the private patent in the same class and subclass that was closest chronologically to the USDA patent, with the general rule being to alternate between taking the patent immediately following the USDA patent and taking the patent immediately prior to it. A preference was given for patents which were originally classified in the same subclass as the USDA patent; in casas where this was impossible, a patent cross-referenced to that subclass was used. The detailed data on these patents is the same as for the USDA patents.

For the private sample from the 1960's, the same method was used. In this case, however, no citation data were obtained; only data regarding date of application, number of claims, state or country of origin, and number of times subsequently cited were used.

Further funding would allow a complete time series of USDA patents to be obtained for 1966-79; a parallel time series of private patents; and would permit the patent data to be computerized so that several statistical hypotheses could be tested, as well as aid in simpler but equally important tabulation.

Appendix 3

Citing Journals by Category

The following journals form the set from which publication and citation data were drawn. Those chosen were surveyed by both the 1967 and 1979 editions of Science Citation Abstracts (SCA). They generally represent the most often cited journals in their fields. They are divided into four categories: Food Science, Ariculture, Materials Science and Other. The last category contains the journals which had the greatest number of citations of a sample of agricultural research station authors. This sample consisted of the first fifty authors from the Northern, Eastern and Western RRC's for 1966 and 1978, and to compensate for the absence of 1966 Southern data, we gave the first fifty from the Southern RRC for 1978 double weight. All journals with 3 or more citations of these researchers were chosen. In some instances a journal was classified in both the "Food Science" and "Agriculture" categories by SCA; in these instances, the journal was classified as "Food Science" only.

Food Science

American Journal of Clinical Nutrition
Cereal Chemistry
Food Engineering
Food Manufacturing
Food Technology
Journal of Agricultural and Food Chemistry
Journal of the American Oil Chemists Society
Journal of Dairy Research
Journal of Dairy Science
Journal of the American Dietetic Association
Journal of Nutrition
Journal of the Science of Food and Agriculture
Netherlands Milk and Dairy Journal
Qualitas Pantarum - Plant Foods for Human Nutrition
Sugar Journal
Zeitschrift fur Ernahrungswissonschaft

Agriculture

Agricultural and Biological Chemistry
Agricultural Engineering
Agrochimica
Agronomy Journal
American Potato Journal
Annales Agronomique
Annales de Technologie Agricole
Australian Journal of Agricultural Research
Animal Production
Annales de Zootechnie
Australian Journal of Soil Research
Canadian Journal of Animal Science
California Agriculture
Crop Science
Euphytica
Experimental Agriculture
FAO Plant Protection Bulletin
Hilgardia
Horticultural Research
Indian Journal of Agricultural Sciences
Indian Journal of Animal Sciences
Irish Journal of Agriculture
Journal of Agricultural Engineering Reseach
Journal of Economic Entomology
Journal of Animal Science
Journal of Soil Science
Journal of Soil and Water Conservation
Journal of Horticultural Science
Journal of Range Management

Agriculture (continued)

Landkauforschung Volkenrod
Landtechnik
Maydica
New Zealand Journal of Agricultural Research
Pest Control
Plant and Soil
Poultry Science
Soil Science
Soil Science Society of American Journal
Soviet Soil Science
Scientia Horticulturae
Revue de l'Agriculture
Revue de Zoologie Agricole
Soil Science and Plant Nutrition
Turrialba
Weed Research
Worlds Poultry Science Journal
Zeitschrift fur Pflanzenzuchtung

Materials Science

American Dye Reporter
Journal of the Society of Dyers and Colourists
Journal of the Textile Institute
Textile Research Journal
Textilveredlung
Fette Seifen Anstrichmittel
Appita
Norsk Skogindustri
Paperi Sa Puu-Papper Och Tra
Papier
Svensk Papperstidning
Tappi
Zellstaff Und Papier

Other General Scientific Journals

American Journal of Botany
Acto Crystallographic, Sections A and B
Applied and Environmental Microbiology
Analytical Biochemistry
Analytica Chimica Acta
Archives of Biochemistry and Biophysics
Annual Review of Phytopathology
Angewandte Chemie - International (Edition in English)
Biochemical Pharmacology
Bulletin De La Societe Chinique De France
Biochemistry
Biochimica et Biophysica Actn
Biochemical Journal
Bulletin de la Societe de Chimie Biologique
Chemische Besichte
Canadian Journal of Chemistry
Chemical Reviews
Comptes Rendus Hebdomadaires Des Seances De L Academie Des Sciences Serie C
Chemical & Pharaceutical Bulletin
Experientia
European Journal of Biochemistry
Journal of the American Chemical Society
Journal of Applied Polymer Science
Journal of Bacteriology
Journal of Biological Chemistry
Journal of the Chemical Society (all editions, A-P2)
Journal of Chromatography

(Other Scientific Journals)

Journal of Chemical Physics
Journal of Physical Checmistry
Journal of Cell Biology
Journal of General Microbiology
Journal of Immunoloy
Journal of Lipid Research
Journal of Polymer Science (all)
Journal of Organic Chemistry
Journal of Molecular Biology
Journal of the Association of Official Analytical Chemists
Lacet
Metabolism
Mycologia
Nature
Naturwissenschaften
Lipids
Plant Physiology
Phytochemistry
Science
Tetrabedron
Zeitschrift fur Natur for schung (all)

Commissioned Paper III

NATURE AND FLOW OF BENEFITS FROM AG-FOOD RESEARCH

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Office of Technology Assessment
U. S. Food and Agricultural Research
Work Group II

IR-6 Information Report No. 5

December, 1980

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GLOSSARY

ag-food research - an abbreviated term defined to include all research related to inputs used in agriculture and forestry, farm and forestry production and harvesting activities; and the storage, preservation, processing and fabricating, and distribution over time and space of all products originating with farms or forests.

applied research - research with a commercial objective; the work of turning basic research into products or processes.

a priori - described by reasoning from self-evident propositions.

average rate of return - the average net value of all dollars invested.

basic research - research without a specific commercial objective.

capital formation - additions to the stock of fixed assets.

ceteris paribus - all else being held constant.

competitive market - a market for a homogenous good in which there is a large number of buyers and sellers of which no individual can affect the market price.

complement - a good which is consumed more (less) when the price of a related good falls (rises).

consumer surplus - the excess of the amount consumers are prepared to pay for a good (rather than go without it) over the amount actually paid for it.

demand - a schedule of the quantities of a good or service consumers are willing and able to buy at different prices.

economic surplus - the sum of consumer and producer surplus.

income elasticity - the responsiveness of the quantity demanded of a good to a change in income of consumers.

integrated pest management - substituting information on pests for pesticides in an agricultural commodity production function.

marginal product - the additional output from the last input employed.

marginal rate of return - the net value of the last dollar invested.

marketing margin - the difference between farm price and retail price; includes processing and transportation costs, etc.

multiplier effects - a measure of the effect on total national income arising from a unit change in one of its components.

price elasticity of demand - the degree of responsiveness of the quantity demanded of a good to changes in its price.

price elasticity of supply - the responsiveness of the quantity of a good supplied to a change in its price.

value of marginal product - the additional revenue generated from the last unit of an input.

ABSTRACT

This document contributes to an assessment of ag-food research requested by the Office of Technology Assessment, United States Congress. It addresses the nature of benefits stemming from ag-food research and the flow of these benefits relative to the funding sources. Topics addressed include: 1) motivating forces in the development of ag-food research programs and institutions; 2) kinds of benefits stemming from ag-food research; 3) beneficiaries of ag-food research; 4) linkages of beneficiary groups with funding sources; 5) returns from ag-food research relative to other research and development investments; and 6) implications for levels of funding and funding mechanisms for ag-food research.

Motivating Forces in Development of Ag-Food Research

Research programs and institutions evolve from motivating forces whose origins are the recognition of constraints on societal goals and the will of the populace to relax the constraints. Ag-food research programs and research performing institutions evolved from several motivating forces that have changed over time.

The origin of investigation and experimentation in plant and animal production and food preservation evolved from the concern for providing an adequate supply of a variety of foods to local areas in an agrarian subsistence type economy. The goal leading to the establishment of the USDA and a national system of agricultural experiment stations was to provide the populace of each state with an abundance and variety of foodstuffs from local sources. Increasing labor productivity through introduction of animal-powered machines and later through machines powered by internal combustion engines, fertilization of plants and increased production of animal foods provided a surplus of ag-food products for a growing urban population that was largely the result of migration from farms.

Increasing labor and land productivity, accompanied by specialization in production and exchange, resulted in the gradual transformation of the agrarian economy into a commercialized-industrialized economy serving a national market for ag-food products. The prime motivating force for ag-food research in this economic environment was competition among states as each state attempted to enhance its competitive position in the national market. Competition among suppliers for the national food market (particularly for the more perishable foods) intensified with the advent of mechanical refrigeration, truck transportation and interstate highways. The net result of such intense competition among states for the national food market was an increase in output and lower real prices to consumers.

As transportation and preservation capabilities improved, competition among suppliers of major food and fiber commodities acquired an international dimension. The motivating force undergirding ag-food research programs, however, remained that of maintaining or enhancing the competitive position of producers. The Nation's agriculture competitiveness in world markets was enhanced by research and development (R&D)—particularly for food grains, feed grains and oilseeds. But a declining competitive position for other major sectors of the United States economy (e.g., crude oil and some manufactured goods) in the world market resulted in increased reliance on ag-food exports to offset an increasing trade deficit in other sectors. This provided further incentive for individual states to support ag-food research to capitalize on the expanding international markets.

More recently the issues of consumer nutrition and food quality and safety are motivating forces undergirding ag-food research. Emphasis was first on protein and the balance of essential amino acids in the diet, with the mineral and vitamin content of foods also receiving attention. Nutrition concerns now have shifted to the issues of excessive consumption of fats and sugars as related to obesity and other health problems, and the impact of food additives and preservatives on human health.

Increasing pollution of air and water, and mounting industrial and household wastes were among other major issues surfacing in the 1960s. Research intensified on ways to maintain a clean environment, to conserve and manage soils and water, to develop alternative sources of fuel and on alternate technologies for producing, preserving and distributing food. The energy crunch of the 1970s, accompanied by a rapid escalation of food prices, again directed emphasis to the cost and availability of food to consumers. In addition to maintaining producer welfare, the objective of constraining the upward pressure on food prices to American consumers is becoming the prime motivating force undergirding ag-food research with the emphasis on postharvest technology and food distribution. Increased efficiency, particularly in food distribution, offers the greatest potential for constraining the upward pressure on food prices.

Nature of Benefits from Ag-Food Research

People individually and collectively strive to improve their well-being. Research constitutes an investment by the private and public sectors that contributes to this societal goal. Benefits of research are constrained by: 1) a time lag between the initial investment and the production of knowledge and between implementation of technology and the flow of benefits; 2) spillover of benefits from the public sector research to the private sector, and from the private sector research to society, that limits funding; and 3) uncertainty associated with investments in ag-food research with only a small portion of the projects having high payoff. It also is difficult to determine, a priori, which projects will be productive---particularly for basic research.

Primary benefits of ag-food research include an expanded output and the universal availability of food and fiber. These have come about through an increased supply of products and reduced losses in quantity and quality of products through preservation and processing. Research on production, processing, preservation, transportation, marketing and distribution of food contributes to increased supplies and lower prices. Research has also improved the quality and safety of food and contributed to better human nutrition. Product quality and safety contribute to nutritional status and health of individuals and subsequently to reduced health care costs.

Expansion of ag-food activities contributes to economic growth by stimulating increases in output in other sectors due to the linkages among subsectors---input supplying, primary production, processing, marketing and distribution. These changes also rebound throughout the USA economy because of interdependencies among other sectors and the ag-food sector. Ag-food research that results in changes in output of the ag-food sector has expansionary impacts on other sectors of the USA economy with attendant changes in incomes.

One of the lesser documented effects of ag-food research is its impact on environmental quality. It is debatable as to whether the modernization of agriculture has given rise to more environmental problems than it has solved. Technological advances of agriculture have enhanced the potential of the natural environment with respect to other amenities in addition to food production. Current environmental problems associated with pest control, soil and water management and waste disposal stem from constraints on rural land---i.e., the capacity of the natural environment to absorb industrial and household wastes. Recognition of this constraint has led to a redirection of ag-food research. The research objective that has evolved is the maintenance of agricultural productivity while reducing the adverse impacts on the natural environment.

Knowledge and skills embodied in people is a part of the national capital stock and is necessary to stimulate innovations and implement technologies. As labor efficiency advanced in the ag-food sector, labor was released to provide an ever increasing array of higher order goods and services. The increasing availability of all goods and services indirectly resulted from advancing labor productivity in the ag-food sector. However, labor displacement and individual hardships did occur in this process. Migration of unskilled persons from farms to cities contributed to urban ghettos that have persisted to date, although this migration stream has about run its course.

Increasing productivity in the ag-food sector also provides nonhuman capital to activate such economic activities as mining, manufacturing, commerce and a myriad of services. It is production in excess of consumption that provides for the formation of new capital. The banking-credit mechanism provided most of the investment funds necessary to acquire capital goods as the economic system evolved and became more complex and sophisticated. Nonetheless, production in excess of current consumption undergirds and sustains our sound banking-credit system.

Among the less quantifiable and less documented benefits of ag-food research are the reduction of drudgery and the increasing leisure time of farm workers. The extremely hard physical work of multitudes of farm laborers required to produce the ag-food output at the turn of the century has been replaced with a much smaller farm labor force working under less adverse physical conditions. Such improvements in working conditions also have been extended to workers in food-fiber processing, fabricating, storage and distribution activities. Although these kinds of benefits do not carry monetary value, they nevertheless contribute to the well-being of the USA populace.

A more recent major benefit stemming from ag-food research is the positive contribution of agricultural commodities to the international trade balance of the USA. An increasing volume of exports of ag-food products has partially off-set the rising volume of imports of oil and manufactured goods. In essence, ag-food products have provided much of the exchange necessary for these USA imports. Research undergirds the advancement of production technology and sustains the strong competitive position of the USA in international food commodities markets.

Beneficiaries of Ag-Food Research

Analysis of the flow of benefits from ag-food research focuses primarily on the distribution of benefits between domestic producers and consumers. The analytical framework is the concept of "economic surplus", partitioned into that part which accrues to buyers of ag-food products (consumer surplus) and that which accrues to sellers of the ag-food products, (producer surplus).

Because domestic demand for farm products is not very responsive to price, an increase in production results in a proportionately larger decrease in price and reduced gross farm income. Thus, the benefits of technological advances that increase output accrue largely to consumers. However, export markets recently have become increasingly important to the USA farm sector. Benefits from technological changes in the production of export commodities, that traditionally accrued to domestic consumers, now may be captured by domestic producers and foreign consumers, unless these benefits are mitigated by public policies. As related to farm size, the benefits from ag-food research have different impacts on various groups of producers. Technology has contributed to economies to size in farming, thus benefiting large farms relative to small farms. This results in fewer farms and declining rural communities with accompanying social problems.

Innovations in the marketing sector, in nutrition, product quality and safety impact on farmers also. Research on human metabolic mechanisms has led to dietary goals that called for restructuring of the American diet. These goals suggest reduced consumption of livestock products and sugar, and expanded consumption of whole grains, fruits and vegetables. Technological change in the marketing sector affects the cost structure for marketing services and also affects both retail and farm prices, depending on the degree of competition among the marketing firms.

Research that changes the relative productivity of factors also has an impact on the distribution of income. Most research has reduced the proportion of total farm income attributed to labor and increased the proportion attributed to capital. Technological changes impact on certain groups of labor. Workers whose skills complement agricultural innovations (e.g., skilled machine operators) have experienced an increase in their real income. However, unskilled workers who performed the same work that also can be done by mechanical innovations have experienced a decline in the demand for their services. Some of these workers have remained in agriculture and others without marketable skills have migrated to urban centers, and both groups face prospects of declining real incomes.

Consumers benefit from ag-food research through expanded quantity, lower prices and improved nutrition and safety of food products. Research that improves the safety and nutritional content of food benefits consumers through improved health. However, impacts of ag-food research differ among consumers by income levels. Estimates of the benefits resulting from ag-food research (discounted to present value), accruing to groups with various income levels in the USA, ranged from $16.20 for the lowest income group (less than $5,000 annually) to $30.74 for the highest income category (greater than $20,000). Although the absolute level of consumer benefits for the highest income group was twice that for the lowest income group, the ratio of benefits to income was almost four times higher for the lowest income class than for the highest income class---thus ag-food research has the greatest relative beneficial impact on low income households.

Research in the ag-food sector leads to new products and technology that increase both agricultural productivity and national income. The contribution of agricultural productivity growth since 1940 to national income in 1979 was estimated to be $111.8 billion (or 5.8%) greater than it would have been without the increases in agricultural productivity over the past four decades. This enhancement in national income is attributable largely to ag-food research.

Foreign consumers and producers also have been impacted by ag-food research in the USA. Increased supplies of food products moving through export markets benefit foreign consumers. However, incomes of foreign producers of these or competing products are reduced under free trade. Ag-food research that increases stocks provides for international food aid. In terms of welfare effects on foreign consumers and producers, the impact of food aid is similar to that of commercial exports.

The USDA and the State Agricultural Experiment Stations are the largest publicly funded ag-food research agencies. Ag-food research management has attempted to optimize the use of continuous and discretionary funds. Discretionary funds usually support the more basic research, contribute to institutional recognition and help assure further support. In this sense, both public research institutions and the scientists are direct beneficiaries of research funding. Little evidence exists, however, to support the contention that public ag-food research institutions and scientists are self-serving and tend to perpetuate their own self-interests and welfare. Further, compensation to ag-food research scientists does not account for much of the rising costs of conducting ag-food research. Average annual rates of salary increases for scientists was only 5.3% during 1973-1978, considerably less than most other workers. However, the rate of increase varied among individuals.

Relationship Between Beneficiaries and Funding Sources

The major sources of public support for ag-food research are federal and state government appropriations funded by tax revenues. Analysis of benefits to costs of ag-food research is related to effective tax rates and benefits for income classes. The benefit-cost ratio ranged from 12.37 for the lowest to 1.20 for the highest income household. Ag-food research tends to redistribute income from higher to lower income groups. However, all income groups receive net benefits from public investments in ag-food research.

A continuing issue is that of the optimal level of state and federal funding. Spillover benefits among states generally are not accounted for by policymakers. This provides strong justifications for federal support of state ag-food research. But federal-state funding methods generally are not based on the spillover benefits among states and regions. Ratios of federal-state expenditures for ag-food research and extension indicate that the federal government financed all of the spillover benefits in only three regions---Northern Plains, Appalachian and Mountain. In aggregate, the ratio of federal-to-state expenditures is only 1.38 compared to a ratio of 1.73 for the spillovers-to-internal regional benefits. The federal government's contribution to ag-food research and extension should be increased 25% to align regional funding support with average regional benefits. Several regions would require a greater percentage increase in federal support to yield an equitable distribution across all regions.

Also, benefits from public sector research accrue to the private sector and private sector research benefits accrue to society. No specific studies have been made for the agricultural processing industries, but studies of the distribution of gains from private R&D in several industries indicate that the benefits accruing to society are at least as large as the direct benefits to the firms conducting the R&D. Thus, societal returns tend to be roughly double the private returns on the R&D investments.

Private sector research in food processing, handling and marketing is characterized by: 1) a focus on short-term applied problems with expectation of a profit from the research investment; 2) extremely limited, basic research into how biological, economic and social systems function; 3) little concern for consumer surplus or net social benefits; and 4) a reluctance to release knowledge that might benefit competing firms, thus thwarting industry efficiency and competition.

The private sector benefits from public research embodied in products (e.g., chemicals, mechanical devices, seed varieties). Most of the R&D in these areas is done by the private sector, but public research activities also are maintained as spillover provides substantial social benefits. In the absence of public support, the direction of the research might tend to be strongly biased toward proprietary, mechanical and chemical technologies. Public research also enhances competition in the private sector.

These relationships hold for funding of public research through producer and processor checkoffs or comparable funding arrangements. These types of funding constitute a collection of private firms supporting public research in their own self interests. Promotion funds tend to focus the research on short-run applied R&D activities that benefit the groups providing the funds.

Social Returns from Ag-Food Research and Other R&D in the USA

Empirically estimated rates of return on ag-food research investments abound, and predominately are in the range of 30 to 40% annually. However, the range of estimated rates of return is from a low of 23% to a high of 100%. The obvious conclusion from these consistently high rates of return is that ag-food research has a high social payoff and is indicative of underinvestment by the public sector. Economic efficiency calls for investments to be allocated in such a manner that rates of return for each additional dollar are equal in all categories. However, relative rates of return as an indicator of misallocation (i.e., underinvestment) of public funds largely have been ignored by public decision-makers.

Ag-food research appropriations have been limited by legislators' perceptions of excess capacity in agriculture and the uncertainties of future benefits from the research. Although expected returns are high, uncertainty in these expected returns is perceived because of the difficulty in quantifying the relationships between ag-food research investments and the economic benefits stemming therefrom.

Evaluations of industrial R&D indicate direct rates of return on privately-financed R&D of 25 to 30% with indirect benefits at least as large as the direct benefits. There is, however, little evidence of positive impact of government financed R&D on productivity growth in manufacturing industries. In nonmanufacturing industries, the impact of government-financed R&D was not clearly established.

The rate of return to R&D in the private sector also varied from a high of about 100% for chemicals, drugs and petroleum to a low of 2 to 3% for electrical equipment, aircraft and missiles research. Average social rates of return from private investments in new industrial technology have tended to be relatively high, from 30 to 50% annually during the 1950s and 1960s---equivalent to ag-food research. Moreover, the marginal social rate of return also seems to be high, at least 30%.

Concepts, such as rates of return, provide the basis for evaluating the economic impacts of R&D. Non-monetary benefits to society from R&D are not readily quantifiable, but publication of scientific and technical findings is a proxy for R&D output. The USA proportion of the world's journal literature for all fields of inquiry was 38 to 39% during 1973-1977. Also, USA scientific and technical articles are cited extensively by scientists in other nations, indicating that USA R&D is relatively influential in world science.

Ag-food research also reduces the cost of other federal programs---notably the food stamp program, other food aid programs and food costs for maintaining a military capability. The cost of food aid programs is directly linked to the retail costs of food that, in turn, depend on the productivity and efficiency of the ag-food sector. Food requirements for the armed forces are among the other federal activities heavily dependent on ag-food productivity and efficiency as it relates to costs. Moreover, food cost is a substantial component of the Consumer Price Index that is used as leverage to increase salaries and wages of personnel employed directly by the federal government and to increase social security, retirement and welfare payments.

Implications for Funding Levels and Funding Mechanisms

The funding of ag-food research is justified on the basis of benefits stemming from the research. Government investments in education, research and development enhance economic productivity and contributes to social tranquility. Productivity can be quantified and documented; social tranquility cannot. Research related to the ag-food sector contributes to economic productivity and hence to the creation of wealth.

Consumers (taxpayers) support ag-food research and reap benefits well in excess of costs. But there are issues of equity due to the interstate and international flow of food, fiber and related commodities. Producers (including farmers) benefit from expanding demand (domestic and foreign) and from reduced costs. The distribution of consuming population among states is related to distribution of primary ag-food production only to a very limited degree. Thus, from the equity consideration of the geographic distribution of costs associated with ag-food research and the benefits flowing from this research, exclusive federal funding of ag-food research would be the most equitable. Conversely, federal funding, relative to individual state funding of ag-food research, has decreased as the interstate flow of commodities has increased. Subsequently, taxpayers in food surplus states are subsidizing consumers in food deficit states, and the degree of subsidization is increasing steadily.

The equity issue clearly supports federal funding of ag-food research relative to individual state funding. It does not, however, resolve the issue as to whether federal, state or private agencies (firms) conduct the research; nor does it resolve the issue of the level of funding in total or for specific programs. The relatively high rate of return on the current level of public investment in ag-food research supports the argument for an increased level of funding.

There are two basic methods of funding---continuous and sporadic. Continuous funding must be in terms of stable real dollar flows, i.e.,.it is not continuous and stable until it is adjusted for inflation. The most important consideration for maintenance and enhancement of scientific capability is consistent and reliable funding under rather specific ground rules for each institution.

Sporadic funding takes different forms and is used for different purposes but its essential feature is the unreliability from the perspective of the individual institution. It cannot be used effectively to maintain quasi-permanent staff and long-term programs. It can be used, however, to initiate new programs (seed money), provide specialized equipment, and additional support staff, or gain a greater degree of control over the use of funds by the funding source, i.e., promote pet or popular research programs.

Continuous and reliable funding is more effective than sporadic funding in producing new knowledge from ag-food research. However, considerable attention must be devoted to issues of: 1) the rate of real dollar change over time for the total ag-food research programs; 2) programs to be expanded or contracted proportionately to the total; 3) the most equitable source of funding given the distribution of benefits; and 4) the most effective method of funding. These issues are being examined in other papers commissioned for the OTA assessment of ag-food research.

INTRODUCTION

In early 1980, the United States Senate Committee on Appropriations and the Senate Committee on Agriculture, Nutrition and Forestry requested an assessment of the research programs related to the ag-food sector. In this report, "ag-food" is an abbreviated term defined to include all research related to inputs used in agriculture and forestry, farm and forestry production and harvesting activities, and the storage, preservation, processing, fabricating and distribution over time and space of all products originating with farms and forests.

The ag-food sector is recognized as the largest sector of the USA economy and provides ample quantities of high quality food, fiber and related products to all USA inhabitants. Moreover, ag-food products are the largest component of USA exports and partially provide exchange necessary to import crude oil and other vital raw materials as well as civilian manufactured goods. The highly successful economic performance of the USA ag-food sector stems from a continuous flow of knowledge and technologies based on research in both the public and private sector.

This paper addressed the nature and flow of the benefits of ag-food research. Empirical verification of some benefits is provided, but it is recognized that many of the benefits are difficult to quantify.

Section I examines the motivating forces and the historical development of ag-food research programs and institutions. Particular emphasis is directed to involvement of the federal government in these programs and institutions. The evolutionary nature of the ag-food sector and the changing nature of the motivating forces also are examined.

Section II develops the nature of the benefits stemming from ag-food research with emphasis on available empirical verification. Again, it is recognized that it is difficult to quantify the benefits in terms of dollar value as is the case with most all publicly funded programs at all levels of government.

Section III identifies the beneficiaries of ag-food research and provides available empirical verification. It has long been recognized that consumers in the USA, and to a lesser degree consumers in countries to which the USA exports ag-food commodities, eventually receive most of the benefits. However, in the evolutionary process, farmers, handlers, transporters and others also accrue benefits.

Section IV examines the relationship between beneficiary groups and funding sources. The interstate and international flows of ag-food commodities contribute to the difficulty in empirical quantification.

Section V compiles existing information on social benefits stemming from ag-food research and other types of private sector and publicly funded research. These benefits include the impact of ag-food research on other federal, state and local government programs.

A final Section VI provides an appraisal of the funding levels and of funding mechanisms. Special emphasis is focused on the long range nature of research programs and the necessity for continuous and reliable funding.

Section I

MOTIVATING FORCES IN THE DEVELOPMENT OF AG-FOOD RESEARCH PROGRAMS AND INSTITUTIONS

Implementation of research programs and associated institutions evolve from motivating forces that originate from the recognition of constraints on achieving societal goals and the will of the populace to relax the constraints. The establishment and evolution of the Land Grant Institutions, the Agricultural Experiment Stations and federal agencies engaged in ag-food research can be attributed to specific societal goals or motivating forces that have changed over time. The evolution and supporting programs of the institutions have changed and evolved in response to the motivating forces.

Subsistence Agriculture

The origin of investigation and experimentation in plant and animal production, and food preservation and its distribution over time and space, parallels civilization. The first law of nature is survival, and survival depends on a consistent supply of quality food. It would be almost impossible to identify the origin of agricultural research. However, the present system of Land Grant Colleges and the USDA was established in 1862. The origin of the agricultural experiment stations and related institutions and activities began with the Connecticut Experiment Station about 1875 (USDA 1975). The major concern underlying the establishment of an experiment station and ag-food research by the USDA was that of an adequate food supply for the local population in an agrarian subsistence type economy. Chemical fertilization to enhance crop yields was the primary emphasis. This embraced testing plant response to chemicals and testing fertilizer materials available to farmers.

Federal legislation (known as the "Hatch Act") created a national system of experiment stations about a decade after the establishment of the Connecticut station. The goal of each experiment station was to provide the populace of its state with an abundance and variety of foodstuffs. Particular research emphasis of the states and the USDA was directed toward adapting a wide variety of plants to local soil and climatic conditions. As crop yields increased and as the land area planted expanded, emphasis gradually shifted to animal foods. Additionally, labor productivity on farms was greatly enhanced by simple hand tools. Substantial boosts to labor productivity included the invention and introduction of animal-powered machines and, subsequently, machines powered by internal combustion engines and petro fuels. The general scarcity of labor relative to land and capital was a motivating force in ag-food research until the late 1800s. During the 20th century, scarcity of land relative to capital was a motivating force for ag-food research and the direction of technological change in USA agriculture.

The self-sufficient agrarian system persisted well into the 20th century. The transition was rather gradual as increasing labor productivity provided a surplus of foodstuffs for a growing urban population. The growth in urban population was heavily impacted by migration from farms. The simultaneous development of the ag-food sector and markets for its products provided for the transition from an agrarian-subsistence type society to an industrialized-commercialized system.

Interstate (Internal) Competition

Increasing productivity was accompanied by specialization and exchange. The agrarian economy gradually evolved into a commercialized-industrialized economy. An ever increasing proportion of the food supply moved through commercial channels. With the advent of rail transportation and manufactured ice, the scope of markets expanded and the populace of any area no longer was dependent solely on the food produced in that locale. A truly national market evolved.

The prime motivating force in this economic environment was competition among states for the national market. Each state attempted to maintain or enhance its competitive position in the market. The market for most major food commodities is highly inelastic at the national level. That is, an increase in output is accompanied by a proportionately larger decrease in price. But, with a few exceptions, each state is confronted with a relatively elastic market---a particular state can increase its output with a proportionately small decrease in price.

The net result of intense competition among states for the national food market included an increase in total output and lower real prices to consumers. The downward pressure on prices was somewhat alleviated by a growing population and increasing real income. Animal foods are more responsive to rising income than the basic plant foods; therefore, the indirect market for grain, oilseeds and forage expanded more rapidly than the national population. Under this economic environment, USA consumers benefited by having an increased quantity of preferred plant and animal products in their diet.

Internal competition among suppliers for the national food market intensified with the advent of mechanical refrigeration, 18-wheelers and interstate highways. In particular, the internal competition intensified for the more perishable foods. The market for fresh milk, for example, changed from a truly local market prior to World War II to a regional and for all practical purposes a national market. Again, the American consumer was the beneficiary of the intensified internal competition among suppliers of food commodities.

International Competition

As transportation and preservation capabilities improved, competition among suppliers of major food and fiber commodities acquired an international dimension. This did not negate the internal competition but did contribute to more elastic markets confronting USA producers, particularly at the aggregated national level. The motivating force undergirding research programs continued to be that of maintaining and enhancing the competitive positions of producers (suppliers).

International competition for world markets also intensified in other sectors. The most publicized is, of course, the increasing dependence of the USA on Middle East oil. This situation arose simply because the competitive position of crude production in the USA deteriorated rapidly as vastly more productive oil fields were discovered elsewhere.

To a lesser degree, the competitive positions of the USA deteriorated in manufacturing---particularly automobiles and electronic based goods. Specialization and exchange---on both a national and international level---are the essence of rising affluence. However, problems emerge when any nation's trade balance is negative; that is, the value of imports exceeds the value of exports.

The USA's deteriorating competitive position in crude oil and some manufactured goods has been offset partly by increasing exports of agricultural commodities---primarily grains and oilseeds. In essence, the advancing competitive position of USA agriculture has partly offset the declining competitive position in other sectors.

Expanding export markets for agricultural commodities have enhanced the elasticity of markets confronted by individual states in the USA. This has provided an incentive and a motivating force undergirding ag-food research programs in individual states. And, to a considerable degree, foreign consumers benefit from the competition among states in the USA for the international food markets. Each state---particularly the major producing states---and the federal government support a research program in ag-food in order to maintain and hopefully enhance the competitive position of the state and the USA in international markets.

Through the round robin of international trade, the ultimate beneficiary of ag-food research is the USA consumer. Ag-food research contributes to lower prices of gasoline, automobiles, television, etc., than would otherwise exist. Cost of many consumer items would be higher from domestic sources than from imports. However, exports of other goods and services are necessary to provide exchange to import. Substantial and persistent trade deficits exert downward pressures on the value of the dollar and subsequently real wages of USA citizens---often accompanied by persistent unemployment. Maintaining the value of the dollar and real wages to USA workers has become a motivating force undergirding ag-food research programs.

Consumer Nutrition and Food Quality and Safety

More recently the issues of consumer nutrition and food quality and safety have emerged as motivating forces undergirding ag-food research. A sharp reduction in world grain reserves, resulting from wide-spread drought during the mid-70s, raised serious reservation with respect to the ability of the world to feed an ever increasing population. Subsequent favorable crop years somewhat have alleviated this concern but it still looms in the wings. There is indeed a precarious balance between world food production and needs of the population. This issue embraces problems in both production and distribution.

Quality and safety of foods have received increasing emphasis in recent years. First, the emphasis was on protein and the balance of essential amino acids in the diet---also the mineral and vitamin content of foods received increasing attention. More recently nutrition concerns have shifted to the issue of excessive consumption of fats and sugars accompanied by obesity and other health problems. Food additives, preservatives and contaminants and their impacts on disease---particularly cancer---are now on the front burner of scientific issues.

Environmental and Resource Issues

Increasing pollution of the earth's air and water and mounting wastes of a highly industrialized-commercialized society were among the major emotional versus scientifically based issues of the 1960s and 1970s decades and continuing into the 1980s. Research on means to maintain a clean environment intensified. The ag-food sector was implicated particularly with respect to nonpoint source pollution stemming from fertilizers and pesticides. Large-scale feedlots and food processing plants can contribute to water pollution and to some extent air pollution.

The energy crunch of the 1970s emphasized the finite nature of much of the world's resources. The goal of more efficient use of petroleum and other resources is becoming a prime motivating force undergirding ag-food research. Also, the research objectives extend into developing alternate sources of fuel and other technologies for producing, preserving and distributing food.

Conservation and wise use of soils, water and timber are longstanding research concerns. However, the energy crunch intensified the need to conserve water and/or use it more efficiently as considerable energy is required for distribution of water---particularly in irrigation.

Cost and Availability of Food to Consumers

The energy crunch of the 1970s, accompanied by the most drastic escalation of food prices since World War II, once again spotlighted the axiom "there is no such thing as a free lunch." In addition to producer welfare, the objective of constraining the upward pressure on food prices to USA consumers has become the prime motivating force undergirding the funding of ag-food research. Ironically, the shift in emphasis from the producer and the competitive position of producing areas to the consumer interests does not drastically change the nature of the research activities.

Consumer welfare and food costs as prime motivating forces in research funding do, however, increase the emphasis on postharvest technology and food distribution. About two-thirds of total food costs to consumers are attributed to the postharvest sector. These costs are largely direct and embodied labor costs. Therefore, increasing labor efficiency in the distribution sector offers the greatest potential for constraining the upward pressure on food prices to consumers.

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NATURE OF THE BENEFITS FROM AG-FOOD RESEARCH

A wide variety of agricultural research activities is underway. Each research activity produces a distinct kind of knowledge. Different research activities have different impacts on various societal goals. Benefits from research activities must be measured according to their contribution to all societal goals. Three unique properties of these benefits are time lags, externalities and uncertainties. A brief comment on these properties precedes the general discussion of benefits.

Benefits of ag-food research are received through time. This raises the question of: What is the proper time period for evaluating the potential benefits from agricultural research? The time path of output response to increased expenditures on research is particularly important in estimating the benefits from research. If the output response is not forthcoming in the same year the investment is made, then the estimated marginal product overstates the marginal returns from research investment.

Evenson (1967) identified the nature of the lag between the research input and increased output. Several potential lag structures were postulated. First, there is a lag involved in the search for new knowledge. Research results become available only after some time has elapsed after the initial investment in research. There is a second lag between the time new research is developed and its actual application. A third lag relates to the period over which the research results are used. A quality improvement may be eroded by disease or replaced by new knowledge or quality improvements. Evenson (1967) found that in response to increased expenditures on research, agricultural output first increased, then reached a maximum and finally decreased with the average response reaching a maximum in the sixth year.

The initial impact of ag-food research may be to benefit a particular group of farmers while the second round or indirect effects of such research may benefit consumers. Selection of an improper time period for evaluating research benefits improperly accounts for these flow attributes. In addition, a time period which covers only the first- and second-round effects could fail to account for potential benefits of economic development, resulting from research (Rausser, et al., 1980). Hence, special recognition needs to be given to the temporal nature of direct and indirect benefits of agricultural research.

A second property of ag-food research benefits is that of externalities. Benefits from investments in ag-food research by private firms can be categorized as: 1) benefits captured by the firm conducting the research and 2) benefits that accrue to other firms and/or consumers. These latter benefits are termed externalities, because the private research investments exert external economic effects on producers and/or consumers that escape the price mechanism so far as the firms initiating the benefits are concerned. If sufficient benefits from the results of the research activities can be captured by the firms conducting the research, then an incentive exists for the private sector to invest in research activities. Factors that help a private firm capture benefits from its research activity include patentability, enforceability and obstacles to imitation for such research (Rausser, et al., 1980). Mechanical R&D traditionally has been conducted by private firms because patent enforceability enables firms to capture a large share of the benefits from such research.

However, in many cases the private firm is unable to capture a large share of the benefits from its own research. This may be the case even with patent rights. Institutional pricing, imperfect consumer knowledge, product emulation and prohibitive costs of collecting benefits from research may contribute to the private firm's inability to capture a large share of the benefits created by its own research activities (Tweeten, 1971).

Government involvement in ag-food research often is justified in order to correct potential inefficiencies and inequities that would otherwise occur as a result of externalities. However, the problems associated with externalities from agricultural research are not eliminated simply by having the government provide the service. Benefits resulting from publicly provided research accrue not only to the producers in the state in which the research is conducted but also may spillover to producers in other states (Peterson and Hayami, 1977). Moreover, agricultural producers capture only part of the total benefits resulting from agricultural research activities. Consumers benefit as a result of expanded farm production and lower prices. Thus, benefits from increased agricultural productivity may accrue to the state conducting the research and to other states, as well. The pervasive nature of agricultural research results affects the efficient allocation of resources and equitable funding of expenditures to improve productivity.

A third property of ag-food research is that of uncertainty attached to the outcome of the research. Not all of the research projects undertaken turn out to be economically successful, but those that are successful have been very productive. When all the successful and unsuccessful projects are considered, the average or expected rate of return on research investments historically has been favorable (Evenson, Waggoner and Ruttan, 1979). However, the distribution of returns among individual projects has a large variance (Tweeten, 1971). It is evident that the innovative process is becoming more systematic, which should improve the probability of success for certain types of research activities (Machlup, 1962). While this statement may be appropriate for applied research, it may not apply to basic research.

The high probability that a research project may not be successful poses serious problems for private firms, particularly smaller ones. A small firm that is able to pursue only a few projects has a high probability that none of the projects will be successful. Larger firms can undertake a larger number of projects, thus, increasing the chances for success. In a large aggregate, such as the United States, the profitability of research investments is more certain and predictable (Tweeten, 1971). In such an aggregate, the productivity of research can be viewed within a framework of risk in contrast to pure uncertainty faced by a small firm. Overall, a high degree of uncertainty about possible outcomes increases the likelihood of underinvestment in research relative to the optimum level for society.

Productivity Growth and Increased Supplies of Food and Fiber

The scientific era emerged with the realization that research to create new products and techniques is a profitable investment (Tweeten, 1979). The profitability of this type of investment results from the fact that technological change expands the amount of output that can be produced from a given level of basic raw materials and labor. This expansion in output results from both production research and marketing research.

Expanded Output Through Production Research

The component of ag-food research designed to increase agricultural productivity is defined as production research. These activities relate to the conservation and effective utilization of resources, particularly soil and water, in addition to plant and animal genetic resources. Technological innovations in this area include new or improved inputs, improved farm products, improved farm management, specialization and farm size. The greatest emphasis in production research has been to improve quality of inputs that increase output per unit of input. With respect to farm-produced inputs, research has been designed to improve crop varieties and breeds of livestock and poultry. Research on purchased inputs has developed fertilizers with improved nutrient contents, new and improved agricultural chemicals, and has produced dramatic changes in farm machinery and equipment.

For the period 1945-1979, technological innovations increased agricultural output 85% with no change in the aggregate level of agricultural inputs (U.S. Department of Agriculture, ESCS, Changes in Farm Production and Efficiency). Substantial evidence shows that the rate of return on ag-food research investment is high relative to most other social investments (Evenson, Waggoner and Ruttan, 1979). Therefore, the total volume of all goods and services is greater as a result of research investment than it would be if these funds had been invested in other alternatives.

Expanded Output Through Marketing Research

Marketing research as a component of ag-food research is designed to provide products where and when needed, in the form desired and with maximum economic efficiency. This research also can make more food available through synthetic processing, upgrading products, preventing waste and providing for the utilization of products previously not considered viable. Improved efficiency in delivery, storage and more efficient utilization of resources reduces marketing costs.

Marketing research also is addressed to societal goals of improved nutrition and health. Among the many areas in which marketing research can be conducted, three areas were given priority in the World Food and Nutrition Study (National Academy of Science, 1977). These areas included: 1) reducing losses in quality and quantity of food; 2) improving food processing and preservation; and 3) improving food marketing and distribution. Marketing research designed to reduce losses in quantity and quality of food obviously will have an impact on the availability of food and its per unit cost to consumers. Food wastes constitute a large potential source of food if appropriate preservation and processing methods can be used. Research on reducing losses due to pests would result in saving more of the product grown. It has been estimated that research on this problem could mean a savings of $1.5 billion annually in the United States (National Academy of Science, 1977). Research on storage and transportation can be effective in reducing consumer food costs. Reducing the loss of fruits and vegetables could increase the supply of these products from 15 to 30% (National Academy of Science, 1977). The benefits from basic research in such areas as establishing physiological and biological interactions and analyzing metabolic processes of microorganisms is more difficult to quantify. However, prevention of food losses and improved food quality are expected to result from this type of research.

Improving food processing and preservation certainly can expand the quantity of food available for consumption. Research on fabricated foods that simulate natural products such as meat analogs from soy protein will establish additional sources of food. Such research is heavily dependent on basic research with applications to food many times being a by-product. Food supplies could be increased if products presently available could be made more acceptable to consumers. Research to develop foods for emergencies and disasters could increase the availability and stability of food supplies.

Reducing Real Costs of Food and Fiber

Consumer food costs can be attributed to the farm-produced portion of food products and to marketing services that change the time, place and form of the product. In order to reduce prices to consumers, research can be conducted at all stages of production, processing, storage, transportation and distribution.

Reduced Costs Through Processing and Preservation

Many food products presently are wasted because of improper methods of preservation. In some cases, a particular treatment can make available for food products that otherwise would be wasted. Research is underway to develop such treatments that would be economically feasible to use. Reducing losses due to wastes would result in cost savings. However, in the area of preservation, many factors, particularly the product's safety must be taken into consideration. In addition, the food must be acceptable to consumers.

Better utilization of food materials through improved processing and preservation may lower food costs because resources would be better utilized. Research on resource utilization can reduce the use of energy and water for processing and, thus, lower food costs. Given the present level of resource utilization, such cost savings could be substantial. For example, drying processes are energy-intensive and could be made more efficient. Fabricated foods can lower food costs by substituting cheaper grain ingredients for more expensive livestock ingredients. Improved knowledge of physical and chemical properties of food will result in savings related to food storage, processing and handling.

Reduced Cost of Marketing and Distribution

Changes in the marketing and distribution of food have been significant in the last 30 years as evidenced by the expansion of supermarkets. The supermarket has reduced by some 15 to 25% the retail cost of food to the consumer (Kramer, 1973). These cost savings were made possible by labor reduction through self-service and large-volume operations in transportation, storage and distribution. As evidenced by these changes, research designed to improve efficiency in food marketing and distribution can be used to lower marketing costs. Better coordination, in both private and public sectors, is needed to move food through marketing and distribution channels.

A more recent study has signaled the potential negative impact on retail food costs from further concentration in the food retailing subsector (Marion, et al., 1979). Greater food costs in noncompetitive retail food markets were not attributed to higher wage rates or transportation costs. Rather the higher costs appeared to be due to inefficiencies and cost-increasing forms of competition. Thus, policy research to develop policies to stop the trend to highly concentrated retail food markets or otherwise improve the competitive performance of the food distribution subsector potentially can result in substantial benefits to consumers.

Food Quality and Safety, and Human Nutrition

The primary purpose of food is to provide nutrients required for body functions. The impact of food quality and safety and human nutrition research programs is to accrue public benefits in terms of: 1) better understanding of human nutrition needs; 2) improved diets and nutrition for individuals; 3) safer methods of food processing, preservation and preparation that have direct impact on the health of individuals; 4) reduced costs through knowledge of nutritional content of food and through food preservation; and 5) improved understanding of food additives, food contaminants and naturally occurring antinutrient components---e.g., mycotoxins, coumesterls, glycoalkaloids---and their role in nutrition, health and safety. These benefits accrue to consumers, but they are difficult to quantify.

With the industrialization-commercialization of the food and agriculture sector, insuring the nutritive value and safety of food gained in importance because consumers were further removed from primary production. Food and agricultural research must provide accurate and up-to-date information about: 1) composition, nutritive value and biological availability of nutrients; 2) nutritional requirements and food consumption practices of individuals and of various income and population groups; 3) impacts of nutritional intervention programs on target populations; 4) nutritive variation in plant varieties and the influence of cultural practices, processing and storage conditions on nutritional content and safety of food; 5) changes in food acceptance, demands for new forms of food, environmental impacts on the nutritional quality of foods and the impact of these factors on health; and 6) the role of animals as food producers.

Nutritional deficiencies continue to add to the problems of poor health and welfare among low income groups. The magnitude and implications of malnutrition for body development of children, either by itself or in combination with various diseases, as well as its impact on human capital formation, labor productivity and general social welfare have been documented by Berg (1976), Call and Longhurst (1972), Ruetlinger and Selowsky (1976), Scrimshaw and Behar (1976), Weisberg, Reese and McDonald (1972) and others. The problem of nutritional deficiencies generally is considered to be one of unequal distribution of available nutrients rather than absolute scarcity. The maldistribution of nutrients has been linked directly to the unequal distribution of income (Pinstrup-Andersen and Caicedo, 1978).

Income is positively correlated with nutritional status, with the low income groups having the least adequate diet and the greatest vulnerability to malnutrition. The prime causes of inadequate nutrition are lack of knowledge with regard to nutritional requirements and nutritive content of foods, the availability of food and the financial ability to purchase it. Food choices also are influenced by socioeconomic and cultural factors such as family life style, health and age of individuals and outside influences, including mass media, advertising and food labeling. Research that provides better insights into the impacts of these factors on the nutrition and health of various population groups benefits consumers exclusively. Both agricultural production technology research and postharvest food technology research affect directly the nature and distribution of these benefits among groups of consumers.

Production Research

Agricultural production research has an impact on current or expected future nutrient supply to low income groups. The impact of an increased commodity supply (resulting from research) on low income consuming groups depends on: 1) the distribution of the increase among all consuming groups; 2) the related adjustments in total food consumption; and 3) the calorie and protein nutrition effects for the consuming population. The relative increase in total nutrient supply has been found to be a poor indicator of relative nutritional impact of agricultural production research. It generally ignores the price and income effects on consumers and the associated consumer adjustment in total food consumption.

Pinstrup-Andersen, Londono and Hoover (1976) found that while new technology resulting in shifts in the supply curve and reductions in commodity price are important in improving human nutrition, the full potential of such technology is obtained only if accompanied by rapid increases in incomes among low income consumers. They conclude that even in the absence of any substantial redistribution of income, greater emphasis on nutritional implications of alternative agricultural production research programs can result in improved human nutrition. This is particularly evident when such research efforts are directed toward commodities in which demand is relatively unresponsive to changes in prices and income---e.g., foods such as corn, rice, wheat and beans that comprise the diets of low income consumers.

Hayami and Herdt (1977) provided further evidence of these impacts of agricultural production research on nutritional status of low income consumers. They examined the impact of a technologically induced increase in supply of rice grown and partly consumed by subsistence farmers in the Philippines. Differences between large and small farmers in the adoption rate of new, high-yielding varieties and marketable surpluses of rice resulted in differential benefits; but smaller farmers gained as much or more as larger farmers when supply increased faster than the rate of growth in demand. The researchers' analysis suggests that a critical factor for attaining a more equal distribution of income (and, hence, improved nutrition of those subsistence farm groups that consume part of their production) is the intensification of efforts to develop technology for the subsistence crop sector.

More recently, Pinstrup-Andersen (1980) has suggested that adding the gains and losses in consumer surplus going to low income consumers, who obtain their food both through the market exchange and through home consumption, provides an estimate of the real income generated by agricultural production research programs through the effect on commodity output. The sum of the price-related change in consumption and the income-related change in consumption, both in market exchange and home consumption, is suggested as a measure for the nutrition-related change in real incomes resulting from the research programs. This measure may be positive, negative or zero for a particular consuming group, depending on adjustments in total food consumption.

Postharvest Research

The primary concern of postharvest food technology is to: 1) preserve food; 2) maintain its nutritional value and safety; 3) provide convenience, variety and acceptability of food products; and 4) distribute food efficiently to consumers. Modern postharvest technologies such as heat sterilization, refrigeration, freeze-drying and packaging are directed to these ends. To the extent that high quality, safe, acceptable and relatively inexpensive foods are made available, consumers are directly benefited. The major impacts of postharvest food technology are in food costs, nutritional quality and safety of food and new or improved products. Each of these will be considered briefly.

Food Costs: An estimated two-thirds of the costs to civilian consumers in the USA are attributed to assembling, processing, transporting and distributing food; one-third of consumer expenditures goes to farmers to cover expenses and to provide a return for investment, labor and management. Direct labor is the largest component of cost in the marketing sector, accounting for 47% of total marketing costs in 1978, with food packaging cost second, accounting for 12%. The third largest component of the marketing bill is the cost of shipping food by rail and truck, accounting for 8% of total marketing costs (USDA, 1979). Rising marketing costs are the main source of rising food costs, with increasing labor costs having the greatest impact on the total marketing costs.

Research to improve productivity of labor in the food marketing sector, particularly in the food distribution subsector (wholesaling, retail food stores and public eating establishments), provides a great potential for maintaining or reducing retail food costs. This is because postharvest labor costs comprise almost half of the marketing cost, or one-third of total retail food costs, and rising labor productivity greatly influences the impact of wage increases on food prices. Labor productivity in the food processing subsector has increased 3.5% annually since 1965, but there has been little increase in labor productivity in the food distribution subsector during this same period. Therefore, increasing labor efficiency in the food distribution subsector offers the greatest potential for constraining increases in food prices.

Nutritional Quality and Safety of Food: Nutritional value and quality of food products refer to the retention of the inherent nutritional and esthetic characteristics of the product that naturally occurs or is introduced by processing and preservation technology. Processing and preservation can improve nutritional value of food, retain it in a stable condition or deteriorate it. A number of operations influence the product from its initial production on the farm to its ultimate purchase by the consumer. These operations relating to storage, handling, shipping, intermediate processing, packaging, delivery to merchants, shelf life and final sale can materially influence nutritional value and quality of the product. Some nutrients, notably vitamins but also proteins and carbohydrates, are sensitive to pH, oxygen, heat and light and are particularly susceptible to damage in the presence of trace elements. The effect of these factors on some of the nutrients is presented in Table 2.1. Postharvest technology research contributes importantly to negating the influence of these factors and the effects of environmental conditions on development of mycotoxins and insect and rodent infestations on nutrient content and safety of the final food product.

Fortification and enrichment of foods are means whereby the nutritional value of food can be increased to benefit a large number of consumers. Actions that have helped improve diets of U.S. consumers include the addition of iodine to salt and fluoride to drinking water. Iron fortification of foods is another example, although current controversy exists regarding the beneficial impacts of iron fortification. Research to improve product quality relates specifically to people as individuals and consumers, and it also strives to upgrade the quality of food products to the benefit of the entire public. Of course, fortification and enrichment of foods generally increase the retail cost of food, and this must be weighed against the benefits derived from the practice.

Postharvest food technology has resulted in some products that actually contribute to nutritional problems. The high-calorie, low-nutrient snack foods and food substitutes that are of lower nutritional value than the foods they replace, are examples. Since an increasing proportion of the food supply is modified by postharvest processing, there is need to consider nutritional value as an integral part of food quality.

Product Development: Numerous paths can be followed between the primary producer and the final consumer in producing final food products. Substitute foods, or ingredients that can be primary or subsidiary sources of food, have been developed by using diverse raw materials, both food and nonfood. Plant protein products can be introduced into the diet either as food ingredients (e.g., soybeans, as an extender, added to ground beef) or as ersatz foods (e.g., simulated chicken or ham). Food blends have been developed from a variety of cereals and oilseeds. Lipid-protein concentrate derived from soybeans can be used as a beverage base. Raw soybeans can be used to produce soy flours, protein concentrates, soybean isolates or textured products.

The nutritive value, protein recovery, consumer acceptability and safety of the products are dependent on the processing activities that the raw products undergo. Attention must be paid to such factors as nutritional quality, storage stability of the product, stabilizers to prevent spoilage and product fortification through the addition of vitamins and minerals. The importance of plant protein in diets is expected to increase rapidly, relative to the demand for meat, fish and egg protein for the industrialized countries. Several possible alternative food sources include: 1) fats or oils from controlled animal feeding and breeding, controlled fish farming, single cell cultivation

Table 2.1. Stability of Nutrients.

Nutrient	Neutral pH7	Acid pH7	Alkaline pH7	Air or oxygen	Light	Heat	Cooking losses, range
Vitamins							%
Vitamin A	S	U	S	U	U	U	0-40
Ascorbic acid (C)	U	S	U	U	U	U	0-100
Biotin	S	S	S	S	S	U	0-60
Carotenes (pro-A)	S	U	S	U	U	U	0-30
Choline	S	S	S	U	S	S	0-5
Cobalamin (B_{12})	S	S	S	U	U	S	0-10
Vitamin D	S		U	U	U	U	0-40
Essential fatty acids	S	S	U	U	U	S	0-10
Folic acid	U	U	S	U	U	U	0-100
Inositol	S	S	S	S	S	U	0-95
Vitamin K	S	U	U	S	U	S	0-5
Niacin (PP)	S	S	S	S	S	S	0-75
Panthothenic acid	S	U	U	S	S	U	0-50
p-Amino benzoic acid	S	S	S	U	S	S	0-5
Pyridoxine (B_6)	S	S	S	S	U	U	0-40
Riboflavin (B_2)	S	S	U	S	U	U	0-75
Thiamin (B_1)	U	S	U	U	S	U	0-80
Tocopherols (E)	S	S	S	U	U	U	0-55
Essential amino acids							
Isoleucine	S	S	S	S	S	S	0-10
Leucine	S	S	S	S	S	S	0-10
Lysine	S	S	S	S	S	U	0-40
Methionine	S	S	S	S	S	S	0-10
Phenylalanine	S	S	S	S	S	S	0-5
Threonine	S	U	U	S	S	U	0-20
Trptophan	S	U	S	S	U	S	0-15
Valine	S	S	S	S	S	S	0-10
Mineral salts	S	S	S	S	S	S	0-3

S = stable (no important destruction).
U = unstable (significant destruction).
Source: Division of Agricultural Sciences, Univ. of California, A Hungry World: The Challenge to Agriculture, July 1974.

(yeast/fungi), selective plant propagation, synthesis from petroleum and enzymic processes; 2) meat or simulated meat products from new animal species, plankton extraction and vegetable sources; and 3) carbohydrates as digestible syrup from cellulose, chemically synthesized sugar or low energy substitutes capable of replacing starch (Holmes, 1973).

Basic studies on these and other new food products may well be the greatest potential for providing a plentiful supply of food nutrients to world consuming populations at minimum or reasonable food costs. The welfare of the consuming population depends on research to develop sound production, processing and distribution practices that, when adopted by the ag-food industry, will insure the availability, quality and safety of the product. Research to: 1) increase the supply of nutrients; 2) determine the nutritional requirements and food consumption practices of various consuming groups; 3) increase the nutritional value of foods; and 4) reduce the potential hazards of naturally occurring toxins, food preservatives or other additives used in processing, insect and rodent contamination, residues of pesticides used in production and inadvertent contaminants, is considered generally to be exclusively for consumers. Producers also may benefit, be unaffected or be disadvantaged by these efforts. Sometimes research to help producers gives an unforeseen bonus that directly benefits consumers. For example, vitamin B_{12}, essential in human nutrition, was discovered by a poultry nutrition researcher. Other agricultural research discoveries important in human nutrition or health include vitamin A, streptomycin, aureomycin, discumarol and selenium.

Expansionary Impacts of Ag-Food Sector Output on Other Sectors

Changes in agricultural production affect an area's economy in two ways. First, a change in agricultural production is directly related to changes in the economy's development. For example, technological innovations cause a direct change in farm earnings, net farm income and/or farm labor requirements and hence, farm labor earnings. Secondly, this change rebounds throughout the economy to produce changes in income in other sectors. Increases in agricultural production as a result of technological change affect not only farmers but also income and employment in agribusiness firms that process and handle agricultural products and supply inputs to farming. Subsequently, agribusiness firms purchase from other industries, and workers in agriculture and agribusinesses spend money for goods and services produced by other industries. Individuals, communities, regions within states and entire states become more aware of the interface between ag-food and other sectors.

Input-output analysis is one technique that is used to measure the impact of increased agricultural productivity on the national economy. The base of the input-output model is the transaction or flow table that measures purchases and sales from one industry to other industries. From this a set of direct coefficients is derived, indicating the input requirement per dollar of output for a given sector. Manipulation of these coefficients results in a set of direct and indirect coefficients indicating the total change in input requirements as a result of a one dollar change in final demand (Doeksen and Little, 1967). The sum of these coefficients is the total change due to interaction among sectors as output changes to meet the increased demand. Coefficients developed from this approach are reported as output multipliers.

Expenditures by one sector constitute receipts to another and, thus, the output multiplier indicates the summation of the revenue generated by the initial expenditure in one sector through spending and respending in all other sectors. It provides a quantitative measure of the impact on all other sectors' outputs resulting from a unit change in output of a given sector. Output multipliers for agriculture and related industries were calculated from the 1972 United States Input-Output Table (Young and Ritz, 1979). The output multipliers were 2.68 for livestock and livestock products, 1.84 for other agricultural products and 2.79 for food and kindred products. These coefficients indicate, for example, that a one dollar increase in livestock and livestock products increases total sales in the economy by $2.68 after accounting for all linkages to the other sectors.

The output multipliers described above provide a measure of the gross benefits resulting from changes in output of the given sectors. Net benefits are measured as the net wage increases (through expanded employment) going to workers in each of the sectors and the net profit gains of firms in each of the sectors (Eddleman, 1977). In an effort to measure these net benefits, White and Miller (1980) estimated personal income multipliers for each state. These multipliers may be interpreted as the direct and indirect change in personal income resulting from a one dollar change in agricultural production, Table 2.2.

Variations in size of multipliers can be attributed to such factors as labor-use intensity in production, profitability of production and overall size of the agricultural sector. The estimated multipliers for one dollar of agricultural production ranged from 22¢ in Wyoming and West Virginia to 72¢ in Florida. The Pacific Coast states, as a region, have the largest multipliers. The northeast and mountain regions have the smallest multipliers.

Table 2.2. Changes in Personal Income Per Dollar Change in Agricultural Production.

Region and State	Multiplier
Pacific:	
Washington	.6954
Oregon	.5502
California	.5852
Mountain:	
Montana	.6500
Idaho	.4867
Wyoming	.2262
Nevada	.4110
Utah	.3842
Colorado	.3817
Arizona	.3923
New Mexico	.4470
Northern Plains:	
North Dakota	.5857
South Dakota	.4142
Nebraska	.5080
Kansas	.3970
Southern Plains:	
Texas	.4141
Oklahoma	.3410
Lake States:	
Minnesota	.5185
Wisconsin	.4467
Michigan	.4557
Corn Belt:	
Iowa	.4979
Missouri	.3939
Illinois	.5956
Indiana	.5691
Ohio	.4857
Delta States:	
Arkansas	.6645
Louisiana	.6501
Mississippi	.4602
Northeast:	
Maine	.4195
Vermont	.4297
New Hampshire	.3876
New York	.3198
Massachusetts	.3744
Rhode Island	.3025
Connecticut	.4749
Pennsylvania	.4956
New Jersey	.3381
Delaware	.5348
Maryland	.4637
Appalachian:	
West Virginia	.2247
Kentucky	.6059
Virginia	.4793
Tennessee	.4131
North Carolina	.6154
Southeast:	
Alabama	.4793
Georgia	.5051
South Carolina	.5260
Florida	.7194

Source: Fred C. White and Bill R. Miller, "Determining Multiplier Effects of Agriculture on the Rest of the Economy," Agricultural Finance Review, ESCS, USDA, Volume 40, April 1980, pp. 19-25.

Enhancement or Maintenance of Environmental Quality

One of the least documented effects of food and agricultural research has been its impact on environmental quality. It may be well to recall that agriculture produced undesirable environmental side effects long before the rapid advance in agricultural production techniques that characterized agriculture in the second and third quarters of the 20th century. Much of the early cotton and tobacco farming in the South resulted in soil erosion and widespread silting of streams and changes in ecosystems. Farm work animals produced large amounts of waste that entailed health hazards to farm families because of inadequate methods for controlling pests attracted to such waste. The dust storms in the Plains States resulted in major environmental threats from attempts to cultivate marginal lands with inadequate soil and crop management technology.

It is still an open question as to whether or not, on balance, the modernization of agriculture has given rise to more environmental problems than it has solved. Ruttan

(1971) and Schultz (1974) set forth the proposition that the technological advances of agriculture have enlarged measurably the biological possibilities of the natural environment, allowing us to eventually have more agricultural output and also more environmental quality components. The development of agricultural technology and the resulting growth in agricultural productivity have allowed substantial reductions in the acreage of major crops such as corn, wheat and cotton. Much of the reduced acreage came about on marginal lands highly subject to soil erosion, and the return of much marginal cropland to pastures and forests reduced many of the kinds of environmental hazards arising from agriculture in the past. The mechanization of agriculture made it economical for farmers to invest in terracing, land leveling, grassed waterways and many other improvements to control water and thereby reduce the adverse impacts of uncontrolled water on the natural environment. Improved soil and crop management technology through mechanized agriculture and the establishment of wind shelter belts in the Plains States substantially reduced the vulnerability of that area to dust storms.

The current environmental problems attributed to agriculture largely involve pest control practices, soil and water management systems, feedlot waste disposal and disposal of residues from food and fiber processing activities. Certainly these current environmental problems are more widespread than those of the past. Environmental problems in the past that may have impacted only farm families and their neighbors now may surface many miles from the farm or processing plant, in densely populated urban areas or in areas of fragile natural ecosystems. Agricultural technology has changed the form and place of the threats, and perhaps the number of people exposed to these threats. The most controversial issue currently pertains to the impact of chemical pesticides used for plant production and protection and of soil sedimentation on water quality.

Ruttan (1971) suggests that the failure to develop agricultural technology (e.g., pest and soil management systems) that would minimize agriculture's impact on the natural environment resulted from an under-valuation of environmental resource amenities. That is, the capacity of the natural environment to absorb the residuals from crop and livestock production has been treated as a free service. Scientific and technical innovations were overly biased toward the development of land substitutes (plant nutrients, chemical pesticides and crop varieties and management systems) that reflected under-valuation of the social cost of the disposal of residuals from agricultural production processes. Recognition of the under-valuation of the social value of environmental services, coupled with regulatory actions on the part of the federal and state governments, has led to redirection of agricultural research efforts in response to the rising economic value of environmental resource amenities.

Examples of this redirection include: 1) integrated pest management techniques; 2) reduced tillage and no-till crop production systems and other soil and water conservation management systems; 3) waste disposal systems using deep lagoons; 4) recycling unprocessed animal wastes through the plant-soil system; 5) recycling processed animal wastes through the animal-plant-soil system, as fertilizer and animal feeds for ruminants; 6) aquatic weed control techniques; 7) methods for disposal of urban produced sewage and digested sludge on agricultural and forest land; 8) organic farming techniques; and 9) alternatives to the burning of grasslands for seed production and croplands to remove excessive crop residues. The aim of these research efforts is to maintain agricultural productivity and profitability while substantially reducing deterioration of the natural environment due to agricultural production and processing activities. Agricultural producers and processors, as well as the public, are all beneficiaries of this research.

It is important to note that not all environmental threats posed by chemicals and pesticide residuals can be placed fairly on agriculture. Public health uses of pesticides, and urban-homeowner uses of pesticides and chemicals have been widespread. Thus, pollution of water supplies and chlorinated hydrocarbons found in the tissue of wildlife and in bottom samples from streams and estuaries are not due exclusively to the agricultural use of pesticides and chemicals.

It also is important to note that agriculture and forestry produce certain positive environmental externalities, such as open spaces and asthetic values. These lands also provide social and personal utility through outdoor recreation, such as hunting, fishing, camping and other forms of outdoor recreation.

It is of social significance to inquire as to who benefits from improvements in environmental quality. Of course, everyone benefits from the reduction or alleviation of human health hazards from improved water quality or air quality or from reduced toxic residues in the food chain. But it would be quite a coincidence if everyone benefited equally from improvements in the quality of fishing waters or increases in the population and range of other wildlife species. The nonhealth-related environmental amenities are strongly demanded in terms of expressed willingness-to-pay by middle- and upper-income households. Environmental restrictions that impede productivity in agriculture will not produce the same benefits and costs for various socioeconomic groups of people. We may expect such restrictions to place an extra burden on the food budgets of low-income families so that more affluent consumers can enjoy these environmental amenities. To our knowledge, no one has come up with the institutional requirements for establishing common property rights for environmental services for achieving compensation to those groups in society who incur the costs of reversing environmental deterioration.

Release of Labor[1] to Other Sectors of Society

An economic system encompasses all the activities of people for the benefit or welfare of people. In man's early history, each person or family had to forage for their own food. This is still true for animals in their natural state and for very primitive societies. Little time was left for other pursuits. In addition to air and water, that usually is attained with little effort, acquisition of food is the first priority of economic activity.

The first tool fashioned to aid in killing an animal for food or planting seed was the beginning of the capitalistic system. That is, man discovered that an intermediate product (perhaps a spear) was an immense aid in his pursuit of a food animal. Eventually people discovered that some excelled in particular activities---fashioning spears, for example---thus specialization was discovered. Eventually the spear-maker got hungry and sought a master hunter to exchange a spear for meat. This was the beginning of the exchange system. As capital enhanced production, it was discovered that an intermediate good aided the exchange system. These are the components of the specialization-capitalistic-monetary exchange system.

Capital may be defined as all intermediaries that enhance the production-exchange process. However, capital is produced by people and is basically embodied labor. The other necessary ingredient in the production process is natural resources---soil, natural vegetation, minerals, water, fossil fuels embedded in the earth and wild animals. People employ the capitalistic exchange system to utilize natural resources to provide goods and services useful to and desired by people. A key element or catalyst is that the wants of people are insatiable.

However, there is a progression of wants ranging from essential food calories to an infinite array of luxuries. Variety and embodied services in foods, in addition to basic gut filler, are among the array of desires.

Knowledge, embodied in people, is a part of the capital stock and is necessary to spring innovations and to develop technologies. Knowledge is gained through basic research, and technologies are spun from applied research. Research related to acquiring food contributes to increasing labor productivity in this sector. Thus, progressively fewer people are required to produce food for the entire populace. Also, advancing labor productivity provides for variety and embodied services in foods---that is, the aesthetic values of food are enhanced. Food and beverage consumption is an important component of social intercourse.

Although human wants are insatiable, the effective demand for total food is rather inelastic---that is, as the desire for food is satisfied, people are prone to focus on higher-order wants. These wants include such things as palatial housing and furnishings, household appliances, automobiles, sports, entertainment, travel, pure leisure and the beat goes on. A major element is that as labor efficiency advances in food production-preservation-distribution, labor is released to produce and deliver an ever-increasing quantity and quality of higher-order goods and services.

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[1] Labor is defined to include all personal services (physical and mental) embodied in products and services both directly and indirectly. In this context labor includes management, planning, research and development and all other human activities intended to enhance the production of goods and services including form, time, place and possession utilities.

Advancing labor efficiency or labor productivity in the ag-food sector is absolutely essential for an economic system to provide an array of higher-order goods and services. Thus, the increasing availability of all goods and services is due indirectly to advancing labor productivity in the ag-food sector.

Although farm production continued to increase dramatically during the 20th century, the farm labor input reached a peak of 13.6 million in 1916 and subsequently declined to a level less than 3.8 million in 1979 (USDA, ESCS). This release of farm labor provided the labor necessary to implement and expand other economic sectors.

However, a substantial part of the labor displaced by increased productivity on the farm was needed for off-farm activities in the ag-food sector. Under the advancing technology in farm production, progressively larger quantities of farm inputs were purchased from the industrial sector. Animal power, produced and fueled on farms, was almost totally replaced by machines powered by internal combustion engines and petro fuels. The inputs of industrial source plant nutrients, pesticides, drugs and feed additives also increased substantially. All these inputs require labor services and include embodied labor.

Additionally, as farm population declined, a larger labor input was required to assemble, fabricate, store and distribute foods. Although it is somewhat more difficult to quantify than decreasing farm labor, total direct and embodied labor in the ag-food sector also has declined relative to the total population and the total labor force. Today, the ag-food sector accounts for about 20% of total employment and 20% of total national income compared with an estimated 35 to 40% of total employment and national income in 1940.

Much of the increasing labor productivity in the ag-food sector is reflected in the declining proportion of consumer income spent for food. This means that additional income is freed to apply toward the higher-order human wants and is the nature of a progressive economy characterized by rising affluence.

Advancing labor productivity in the ag-food sector is the primary catalyst in economic development. Research provides the knowledge base for increasing labor productivity in the ag-food sector. Not only does this provide increasing variety, quantity and quality of food to USA consumers at lower real cost, but it also releases labor to provide a vast array of higher-order goods and services.

Nonhuman Capital Flow to Other Sectors of the Economy

Creation of capital (investment funds) is an essential feature of economic development. Although the banking and credit system is a complex mechanism and beyond the scope of this study, capital is basically created by producing in excess of consumption. Since it was the initial productive activity in Colonial America, agriculture provided the initial capital toward economic development.

A capitalistic system basically is a system that produces intermediate goods---i.e., machines, tools, fuel, etc.---to enhance the production of consumer goods and services---i.e., food, clothing, shelter, etc. The capitalistic system enhances labor productivity with labor defined as all personal initiative both physical and mental. Capital also includes the education embodied in the populace and the technology undergirding the production processes. Advancing technology, implementation capital (investment funds), a populace with the ability and skills to use the technology and a viable market are the components of economic development. In that economic productivity provides the income for a viable market, all components of economic development are a part of or closely related to capital formation. Agricultural commodities provided the exchange necessary to acquire both capital goods and manufactured consumer goods from Europe during the early stages of development on the American continent. Capital goods initially were used to enhance the agricultural productivity under a predominately subsistence type economic system.

Increasing productivity in agriculture subsequently provided the capital to activate such economic activities as mining, manufacturing, transportation, commerce and a myriad of services.

As an economic system evolves and becomes more complex and sophisticated, the banking-credit mechanism provides most of the investment funds necessary to acquire capital goods. The banking-credit mechanism is regulated by and closely tied to the national government. Nevertheless, productivity and markets are necessary to provide the cash flow to maintain a sound banking-credit system. It is the production in excess of consumption that provides for the formation of new capital. In essence, production is essential to undergird and sustain a sound banking-credit mechanism.

Leisure Time and Drudgery

One of the less quantifiable and less documented benefits of food and agricultural research is the reduction of drudgery and the increasing leisure time of farm operators and farm workers. Although these kinds of benefits do not carry monetary value, they are nevertheless important in the advancement of the welfare of the USA populace. Such benefits have also been extended to workers in food-fiber processing, fabrication, storage and distribution.

In some cases, output of farm products per unit of farm labor input has increased up to 80 times what it was at the beginning of the 20th century (Cochrane, 1979). However, the quantification of increased labor productivity on the farm and the substitution of off-farm labor---in the form of machines, tools, fuel, etc.---for farm labor does not reveal the reduction in drudgery. Extremely hard physical work of multitudes of farm laborers was required to produce the food output at the turn of the century compared with a relatively few farm laborers working under less adverse physical conditions in the fourth quarter of the 20th century.

Increasing labor productivity on the farm is reflected in both the output per unit of labor input and a reduction in the intensity of the labor input. The increasing labor productivity also has provided more leisure time for the individual worker. The 60 to 80 hour work week has been replaced by the more typical 30 to 40 hour work week.

International Trade Balance

A major benefit stemming from food and agriculture research is the positive contribution of agricultural commodities to the international trade balance of the USA. The increasing international trade deficit of the USA during the 1970s has been well publicized. The main source of the international trade deficit is the increasing reliance of the USA on oil imports and the rising prices of crude oil imposed by the OPEC cartel. Another source of the international trade deficit is increasing imports of automobiles, electronic goods and other manufactured goods.

An increasing volume of exports of ag-food commodities from the USA has partially off-set the rising volume of imports of oil and manufactured goods. In essence, agricultural commodities have provided much of the exchange necessary for the USA to import oil and manufactured goods. An increasing output of agricultural commodities---necessary to sustain oil exports---is subsequently dependent on a continuous flow of production technology. Research and education undergird the advancement of production technology and sustain the strong competitive position of the USA in international food and fiber commodities markets.

Table 2.3 provides documentation for the importance of agricultural commodities in reducing the magnitude of the USA international trade balance. Agricultural exports increased from a volume of $7.2 billion in 1970 to $34.7 billion in 1979. The trade balance in agricultural commodities increased from a surplus of $1.5 billion in 1970 to $17.9 billion in 1979. This contrasts with a rising international trade deficit in other commodities from a surplus of $1.2 billion in 1970 to a deficit of $45.6 billion in 1979. An international trade deficit places a downward pressure on a national currency, reduces gold reserves, provides exchange for alien ownership of physical assets and contributes to national price inflation. These undesirable economic consequences lead in turn to a reduced standard of living and chronic high levels of unemployment.

Table 2.3. Exports, Imports and International Trade Balance in Agricultural and Other Commodities, USA.

Year	Exports		Imports		Balance	
	Ag	Other	Ag	Other	Ag	Other
			$Billion			
1950	2.9	7.3	4.0	4.8	(-1.1)	2.5
1955	3.2	12.2	4.0	7.4	(-0.8)	4.9
1960	4.8	15.5	3.8	10.8	1.0	4.7
1965	6.2	20.9	4.1	17.3	2.1	3.6
1970	7.2	35.3	5.8	34.2	1.5	1.2
1975	21.9	84.2	9.5	86.6	12.4	(-2.4)
1979	34.7	143.8	16.9	189.4	17.9	(-45.6)

Source: Business Statistics, Biennial Edition. United States Department of Commerce, Office of Business Economics, 1961 and 1977. Survey of Current Business. United States Department of Commerce, Bureau of Economic Analysis, April 1980, Vol. 60, No. 4.

A favorable trade balance in agricultural commodities contributes directly to the well-being of American farmers and commodity processors, handlers and transporters. It also contributes to the well-being of American consumers by providing exchange for imports and contributes to the stability of the American economy.

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Section III

BENEFICIARIES OF AG-FOOD RESEARCH

Studies of the beneficiaries of ag-food research have been focused primarily on the distribution of benefits between domestic producers and domestic consumers. Also, some effort has been directed at the distribution of benefits among factors of production and to the distribution of benefits among producer groups and among consumer groups. The findings from these past research efforts will be reviewed in this section. In addition selected economic principles are presented in order to consider the distribution of benefits among foreign producers and consumers as a result of research activities in the USA.

An analytical framework that can be used to measure these distributional effects is the concept of economic surplus.[1] To illustrate this concept, consider the situation depicted in Figure 3.1 with a typical demand and supply curve for an agricultural commodity. With demand represented by curve D and supply represented by curve S, the equilibrium price and quantity would be P_0 and Q_0, respectively. Economic surplus can be separated into that accruing to buyers, consumer surplus (the area below the demand curve D and above the equilibrium price line, P_0, i.e., area "a") and that accruing to sellers, producer surplus (the area above supply curve S and below the equilibrium price line, P_0, i.e. area "b").

Ag-food research generally results in increased supply, i.e., shifts supply to the right (Figure 3.2). Such a shift results in a lower equilibrium price, and an increase in economic surplus. Consumers receive gains equal to the area a + b in Figure 3.2. Producers would gain area c in Figure 3.2 but lose area a.[2] Several studies have used the concept of economic surplus to quantify the value of agricultural research (Griliches, 1964; Peterson, 1967; Schmitz and Seckler, 1970).

Farm Producers

In order to understand how farmers benefit from agricultural research, it is necessary to understand the market for ag-food products. Domestic demand for ag-food products is highly inelastic, meaning that an increase in the price of food will result in only a slight decline in total ag-food consumption by the average consumer, and vice versa. Thus, an increase in production will produce proportionately lower prices and farm incomes. Also, the income elasticity of demand for ag-food products is inelastic, which means that rising personal income in the USA has almost no effect on per capita ag-food consumption. Thus, the domestic demand for food increases slowly at about the same rate as the rate of growth in the general population. In this situation, technology that increases output in excess of that needed to meet demand growth results in depressed prices. However, within the last decade changes have occurred that affect the benefits accruing to farmers as a result of technological change. Foreign markets have become increasingly important to the USA farm sector. The demand that the U.S. faces in these markets is characterized as elastic, because a given change in quantity will have a relatively small impact on price. With the increasing importance of export markets, total demand (export plus domestic) is more elastic than has been the case historically. Benefits from technological change in the production of export commodities accrue largely to farm producers in the USA, because their increased production will be sold with little impact on the world market price.

Benefits from agricultural research have different impacts on farms of different sizes, producing different commodities and located in different geographical regions (Heady, 1971). Studies indicate that technology reduces per unit production costs more on large farms than on small farms, indicating important economies of size (Jensen, 1977).

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[1] The concept of economic surplus as a measure of consumer and producer welfare is well documented (Currie, Murphy and Schmitz, 1971; Willig, 1976).

[2] Producers can experience gains or losses from an increase in supply resulting from ag-food research, depending on the elasticity of the supply curve.

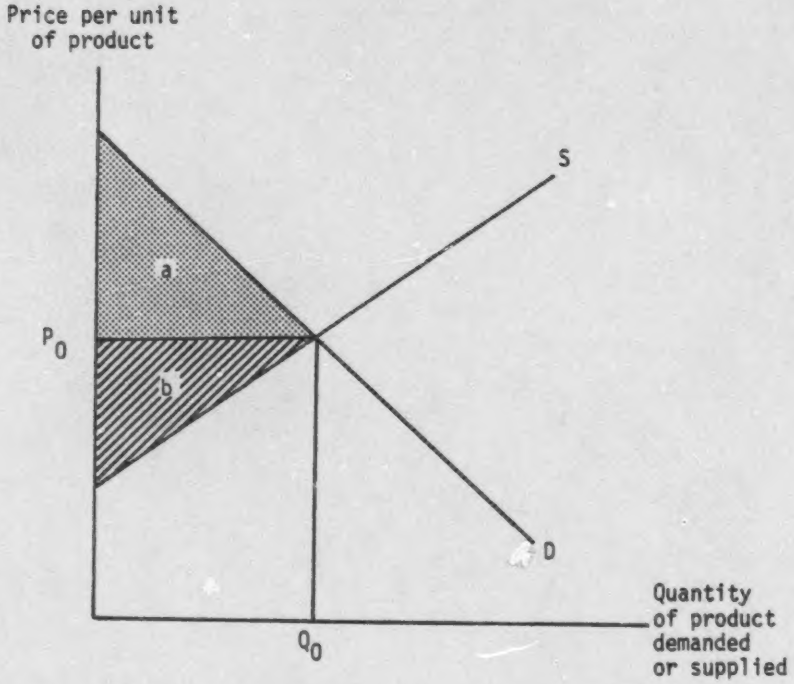

Figure 3.1. Hypothetical Supply and Demand Curves.

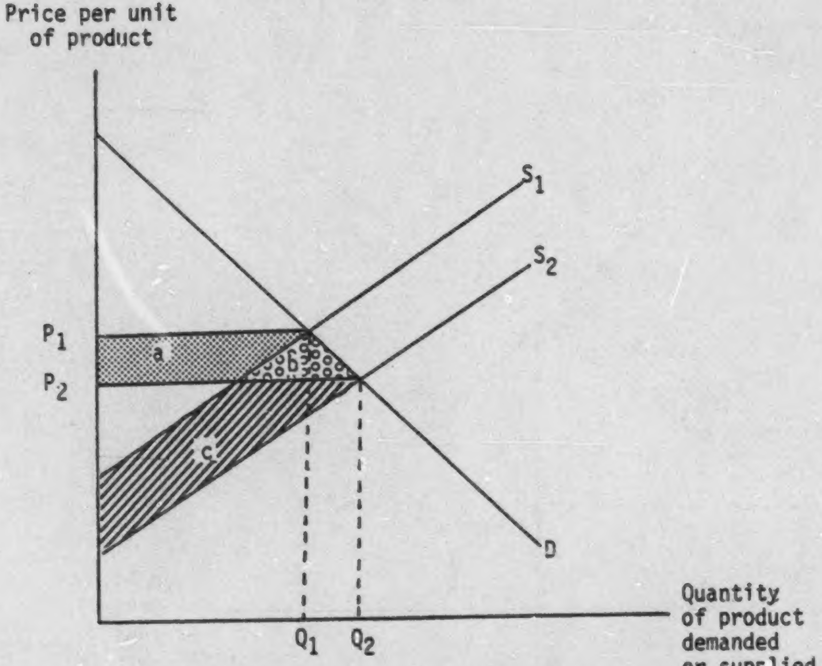
Price per unit of product
S1
S2
P1
P2
a
b
c
D
Q1
Q2
Quantity of product demanded or supplied

Figure 3.2. The Effect of Increased Agricultural Research Investment on Consumers and Producers.

While these studies indicate that research results benefit large farms relative to small farms, research results have not favored large corporate farms to the detriment of family farms. Technology affects farmers according to the speed with which new innovations are adopted. Cochrane (1958) grouped farmers into three categories---early adopters, followers and laggards. Early adopters are able to increase their incomes with new technology that reduces cost of production. However, increased production resulting from new technology in the aggregate depresses prices, and followers gain less from new technology. Finally, laggards are forced to use the new technology in order to survive. Certain mechanical innovations favor large-scale farms of the Corn Belt and Southwest relative to smaller farms in the South and East. Biological technologies that may be unrelated to the size of farms can alter comparative advantages among regions (Heady, 1971). Also, technological innovations often increase the profit of some producers to the detriment of other producers. Technological advances in feed grain production, for example, would lower operating costs for beef, hogs, dairy and poultry production.

Technological innovations in the marketing sector and in nutrition, product quality and safety also may impact on farmers. Research has led to dietary goals that called for restructuring of the American diet (U.S. Congress, 1977). These goals suggest reduced consumption of livestock products and expanded consumption of whole grains, fruits and vegetables. The increased use of chemicals in the production of crops and livestock raises questions concerning the ultimate safety of these products (Timmer and Nesheim, 1979). If the use of some chemicals is restricted, then production costs for commodities using these substances also may increase.

Marketing Firms

A technological change in the marketing sector, such as a reduction in waste or spoilage, affects the cost structure for marketing services. In such cases both retail and farm prices may be affected by reduced marketing margins.[3] The farm price would be expected to increase and the retail price would be expected to decline with reduced marketing margins. These relationships hold for a competitive market structure in which the changes in margins are reflected throughout the marketing system (Tomek and Robinson, 1972). The impact on consumers and farmers of a technological change in the marketing sector is dependent on the price elasticities of supply and demand, and of course, on the magnitude of cost savings resulting from the technological change.[4]

Competition in the marketing sector results in lower cost of marketing services being passed on to either consumers and/or producers. However, there is evidence that the food marketing system does not conform to the purely competitive model (National Commission on Food Marketing, 1968). Marketing firms with some monopolistic power may retain a portion of the cost savings from technological change in the form of increased profits (Tomek and Robinson, 1972). The more competitive the industry, the less incentive there is for private research because the benefits accrue to consumers and farmers. In a less competitive industry, private research is more profitable for the individual firm, and private research may reduce also the level of competition. Another benefit of public research may be enhanced competition and/or reduced concentration in a particular subsector. The benefits from public ag-food marketing research in a highly competitive industry accrue mostly to consumers and only to a limited extent to farmers, if at all, over time.

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[3] Both the derived supply at retail, that is dependent on farm supply and the marketing margin, and the derived demand at the farm level, that is dependent on retail demand and the marketing margin, would shift in a competitive market as a result of a reduction in marketing costs.

[4] For a commodity with supply more elastic than demand, a given change in the marketing margin will change price more at the retail level than at the farm level (Waite and Trelogan, 1951).

Labor and Other Input Supplies

Technology that changes the relative productivity of resources shifts the distribution of income among resources (Heady, 1971). These changes have reduced the proportion of total farm income attributed to labor and increased the proportion attributed to capital. The impact of technological change on farmland's share of farm income is not easily determined. These issues will be examined in more detail.

Changes in the proportion of farm income attributable to labor depends on the type of technology. Labor-saving technology reduces the demand for labor. Mechanical technology that has been developed almost entirely by private sector research generally can be characterized as labor-saving (Evenson, 1980). Estimated income effects indicate that technological changes have increased the marginal physical productivity of labor used in farming (Wallace and Hoover, 1966). The result is an increase in the demand for labor if farm product prices are unaffected. However, as farm prices adjust downward to expanded output resulting from technological change, the demand for labor declines because the demand for agricultural products is inelastic (Bauer, 1969).

The differential impact of technological change on certain groups of labor is evident. Workers whose skills complement agricultural innovations have experienced an increase in their marginal productivity and in their real income. However, unskilled workers who do the same work that can be done by mechanical innovations have experienced a decline in the demand for their efforts. Those workers remaining in agriculture have faced prospects of declining real incomes.

The demand for land is affected also by technological advance in agriculture. Herdt and Cochrane (1966) postulated that technological advance has benefited farmland owners, not necessarily farm operators. They said that farmers view technological change as reducing cost of production and hence are able to bid up the price of farmland accordingly. However, these authors did not adequately address the depressing price effect of expanded production. Heady (1971) argues that rapid increases in agricultural productivity would lower the value productivity of farmland because the extremely low price elasticities of demand for farm products would reduce farm revenue. While the net effect of technological change would be to lower the share of total income attributable to farmland, farmland prices increased during periods in which the government supported prices because of compensatory government programs. With price supports, increased productivity resulted in sizable capital gains to farmland owners (Cochrane, 1965). However, these capital gains must be evaluated in terms of the government programs in effect to support farm prices and not be considered as sole responsibility of technological change.

Benefits Accruing to the Public in General

Consumers benefit from ag-food research in several important ways. These benefits include expanded quantity of ag-food products and lower prices (see Figure 3.2 as an illustration of the net effect on consumers). Furthermore, consumers benefit from improved nutrition and safety of food products. Some of these benefits appear to be concentrated among certain groups of American families. It is estimated that diets of 20% of the households in the United States provide less than two-thirds of the recommended allowance for one or more nutrients (Kramer, 1973). Malnutrition is most evident among low-income families and relationships between diet and chronic illness have been identified (Timmer and Nesheim, 1979). Agricultural research that improves the safety of food products is likely to affect consumers in all income categories. The benefits of such research include improved health and longer life.

In terms of equity goals for society as a whole, planning should take into consideration distributional impacts of agricultural research among consumers of different income levels. The following analysis estimates the distribution of benefits from agricultural research on the basis of food expenditures. Each dollar of food expenditure is assumed to be related to the same amount of research benefits whether the expenditure is made by high- or low-income families.

Data and Procedures to Estimate Distributional Impacts

Multiplying agricultural research expenditures by the marginal value product of research (MVP_R) yields an estimate of total[5] benefits accruing to society as a result of research investment in the ag-food sector. The combined amount of production-oriented expenditures by the Agricultural Research Service, the Economic Research Service and the State Agricultural Experiment Stations was estimated to be $574 million in 1974 (Budget of the U.S. Government; USDA, Inventory of Agricultural Research; U.S. Dept. of the Treasury). The most conservative estimate of marginal value product of research for 1974 was $9.34 billion (Davis, 1979). Half of these benefits were assumed to accrue to consumers.

Lu, Cline and Quance (1979) suggested discounting future returns in order to compare them with present costs. They concluded that the impact of research investment on agricultural productivity lasts an average of 13 years at the national level, reaching its peak at 6 to 7 years after the expenditure and gradually declining. Utilizing distributed lag weights for 13 years, a conservative estimate of the present value of gross benefits (discounted at 10%) accruing to consumers from agricultural research expenditures in 1974 was $1.38 billion.

Gross benefits were distributed over income classes on the basis of food expenditures in each group (Gallo and Boehm, 1978). Total population in 1974 (USDA, Agricultural Statistics, 1978) was distributed over income groups according to percent of total population in each group (Gallo and Boehm, 1978) to get a per capita dollar benefit for each income class. Average benefits per family were calculated using average size family from U.S. Dept. of Commerce data in Current Population Reports. Aggregate family money income in 1974 was $807.9 billion (U.S. Dept. of Commerce, Current Population Reports, 1976). Using percent of total reported income for each income class (Gallo and Boehm, 1978), a benefit-income ratio was calculated for each group.

Distribution of Consumer Benefits

Family size and income characteristics for six income categories are shown in Table 3.1. The six income classes ranged from under $5,000 to over $20,000, and average size family ranged from 2.93 persons in the lowest income class to 3.79 persons in the highest. The present value of average benefits per family for the various income classes also is shown in Table 3.1. These estimates may be interpreted as the benefits accruing to each family as a result of ag-food research expenditures in that year. Even though benefits would be realized through time, this stream of benefits was discounted with a 10% discount rate to find the present value of benefits. Comparison of consumer benefits indicated that average benefits per family increased with the level of family income and ranged from $16.20 in the lowest income category to $30.74 in the highest income category.

In addition to the absolute level of consumer benefits among income categories, it is important to consider the level of consumer benefits relative to income. The ratio of benefits to family income was almost four times higher for the lowest income class than for the highest, indicating that ag-food research has a greater beneficial impact on low-income families than high-income families in relation to family income.

This conclusion supports the hypothesis that agricultural research tends to modify the existing income distribution in favor of the lower-income strata (Pinstrup-Andersen, 1977). However, for some commodities the distribution of consumer benefits from ag-food research tends to be biased in favor of families with higher income. The higher the quantity consumed in the higher income categories relative to the lower income categories (e.g., pork, poultry, beef and dairy products), the more favorable the distribution of benefits to higher income families.

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[5] A measure of average value product of research should be used, but this value generally is not available. The marginal value product can be considered a conservative estimate of benefits.

Table 3.1 Relationship Between Ag-Food Research Benefits and Family Income.

Income Class	Distribution of Population[a]	Average Size Family[b]	Average Family Income	Average Benefits per Family[c] (Present Value)
(Dollars)	(Percent)	(Persons)	(Dollars)	(Dollars)
Under 5,000	18.19	2.93	3,981	16.20
5,000-8,000	14.14	3.15	7,922	19.06
8,000-12,000	21.17	3.28	10,528	20.63
12,000-15,000	14.47	3.48	13,458	22.13
15,000-20,000	16.07	3.68	17,371	25.91
Over 20,000	15.96	3.79	28,953	30.74

[a] Gallo, Anthony E. and William T. Boehm, "Food Expenditures by Income Group," National Food Review, NFT-3, USDA, ESCS, Washington, D.C., June 1978.

[b] U.S. Department of Commerce, Bureau of the Census, Current Population Reports, Series P-60, No. 101, "Money Income in 1974 of Families and Persons in the U.S.," U.S. Government Printing Office, Washington, D.C., 1976.

[c] Total consumer benefits are calculated according to the equation

$$TB_C = 1/2 \times MVP_R \times RE \times D$$

where TB_C is total consumer benefits from ag-food research; MVP_R is marginal value product of research (Davis); RE is production oriented research expenditures in 1974 (Budget of the U.S. Government; USDA, Inventory of Agricultural Research; U.S. Dept. of the Treasury); and D is the discount factor over 13 years at 10% (Lu, Cline, and Quance). Total consumer benefits are allocated to income classes according to the level of food expenditures.

Contributions to Economic Growth

Research investment in the ag-food sector has led to new products and technology that increased agricultural productivity and allowed labor to flow from the farm to the nonfarm sectors. These adjustments in the labor force have raised national income, because average nonfarm income is typically above average farm income. Tweeten and Hines (1965) approximated the contribution of agricultural productivity changes since 1910 accruing to national income in 1963. Estimates for the 1940-1979 period were calculated using a similar procedure (Table 3.2). With only 3.5% of the population living on farms in 1979, the actual national income was $1,924.8 billion. If in 1979, as in 1940, 21.3% of the population lived on farms, then national income would be $111.8 billion (or 5.8%) lower without the farm changes that have taken place since 1940. This $111.8 billion difference in national income can be attributed to advances in agricultural productivity resulting from research and education expenditures in the agricultural sector since 1940.

Table 3.2. Estimates of the Contribution of U.S. Agricultural Productivity Change to the 1979 National Income Since 1940.

Decade or Years	Contribution to 1979 National Income
	(Billion 1972 Dollars)
1940-1950	44.6
1950-1960	36.6
1960-1970	24.6
1970-1975	2.9
1975-1979	3.1
Total 1940-1979	111.8

Costs of Farm Labor Adjustments[6]

Adjustments in farm labor may have adverse effects on some groups (Schertz, 1980). The expanded pool of workers in the nonfarm sector may depress the nonfarm wage rate. Business and consumers profit from this situation and workers already in the nonfarm sector can be affected adversely by the influx of workers from the farm sector. This situation has been undoubtedly important in the past, but is not expected to be very important in the future. The substitution of capital for farm labor can have adverse effects on workers not suited for nonfarm employment because of age, lack of skills or inadequate employment opportunities. While this situation recently has been evident for large numbers of people in developing countries, it also affects many workers in the United States. This problem has associated with it social costs that include unemployed resources and social services for displaced farm workers.

Many rural communities that served populous farming areas deteriorated as the number of farm workers declined. The tendency for people to leave rural areas has affected the viability of many rural commercial enterprises, churches, community services and, in some cases, entire communities.

These are, however, indirect effects that generally were overlooked. The structure of agriculture is highly competitive. Trade-offs that are implicit in changes in production technology are worked out through the market processes. The competitive forces of the market are oriented toward efficiency and operate in a cold and impersonal manner. New technology alters the relative productivity and value of assets, enhancing the value of some and often decreasing the value of others.

Most improvements in agricultural production technology increase the productivity of capital and land relative to labor. They, therefore, generate incentives to substitute land and capital for labor. The story of the vastly increased capital requirements for successful farming is well-known. The decline in the relative importance of labor as a farm input also is well known. Since many farm workers owned only their labor, the value of their assets was decreased through innovations in production and they were forced to look for alternatives. The vast stream of people moving from the nation's farms to the cities since 1940 probably was the largest migration in history.

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[6] This section draws freely from two articles by Bishop (1967, 1974).

Many of those who migrated were able to make successful adjustments and to obtain more productive and rewarding employment in non-farm industries. However, for many the adjustments were painful and costly.

Too little ag-food research was done on the processes of agricultural development as they impacted on rural America. Too often costs were ignored, especially if these costs were incurred in the migration to urban centers. The research that was done did not provide definitive answers to the question of whether the substitution of land and capital for labor in farming and the subsequent massive migration of people to the nation's cities on balance added to the national well-being. The answer probably is in the affirmative, at least over the long pull, but the effects have not been assessed adequately.

There is little question, however, that the ag-food research institutions have been overly imbued by technological research. The same research that yielded increased production of crops and livestock also resulted in the depopulation of rural areas and accelerated the growth of central city ghettos. In the non-ag sector, technology that made possible rapid transportation also yielded polluted air. In these and in other instances, as technological research was introduced, highly important side effects emerged that were not planned. Neither the individuals concerned nor the society sought them. They were not anticipated because the approaches to developing and integrating knowledge into society were too specialized.

In the process of making adjustments to accommodate new technology the old pattern of spatial distribution of population in rural and urban areas was destroyed. It was not planned that the distribution would be changed but the structure that prevailed was inadequate to accommodate the more productive technology. The 160-acre tract was and remains an operable unit with a particular set of technology. Sacrifice of it was a necessary part of the tradeoff involved in transferring to more productive technology. Even today it is possible to return to the 160-acre farm but few would be willing to make the necessary reduction in food supply.

Technological changes have had far reaching effects upon the development of rural America. The ag-food research institutions have not been as alert as they should have in anticipating these effects and in the development of means of coping with undesirable effects. As a minimum, the secondary effects of changes associated with the application of knowledge generated through the ag-food research programs should be identified. This, of course, is difficult to do because of the pervasiveness of the effects.

The effects of technological change in American society are pervasive partly because of the fact that they do not come as a single shock but as a series of continuous shocks. The combination of publicly funded technological development and private industrialization carries an implicit commitment to constant change in production technology, making it difficult to isolate and measure the effects of any particular change. Even so, the major course of development is clear, and the structural changes that have been brought about as a result of the adoption of new technology have been secondary changes that were made in an attempt to adjust to the new technology. No attempt has been made to develop technology consistent with any particular pattern of social and economic organization. Instead, the development of technology to provide the most efficient production of commodities has been emphasized, and we left the pattern of social and economic organization to be determined by market forces as they adjust to that technology.

It was erroneously assumed that the development of technology to enhance the supply of products would automatically enhance national well-being, and that a desirable economic and social structure would be worked out through the market forces. In many instances this did not follow. Serious problems of national consequence emerged that were largely external to the specialized systems of research and decision making that led to the development and introduction of the new technology.

The continuing concern over urban and rural development, resource conservation, environmental quality, structure of agriculture and the quality of life generally derive not from fear of inability to produce sufficient ag-food products to meet national needs. The ag-food research institutions that have been created in this country have demonstrated beyond question their efficiency in generating and applying knowledge to achieve increased production of commodities. No more productive system is known.

Instead, the concerns over national development derive largely from the social costs of technological development that have been largely ignored in the past. They reflect continuing questions with respect to how the people fare under conditions of national economic growth.

American society is becoming increasingly service oriented. The costs of providing public and private services are affected importantly by the spatial distribution of the population. Technological change will continue to have a major impact upon the location of employment and population, but it should not be the dominant factor that it has been in the past. A broader frame of reference than the legacy of the industrial revolution must be sought. Fundamental questions concerning the organization of society must be addressed. What organization of society, spatially and structurally do we want? Is this organization consistent with reasonably efficient production of goods and services? If not, what kinds of tradeoffs appear possible and desirable? The nation must assess how it can improve the quality of life for its people within the framework of its resources and the knowledge that can be developed and brought to bear upon them. Certainly, this includes the exploration of ideas about how a society is organized and operates.

The land-grant universities and ag-food research institutions were not created to chart a course for national development. Indeed, they are ill-suited to do so. However, as centers of learning, dedicated to the discovery of truth, they do have a responsibility to examine critically the functioning of American society, to explore alternatives, and to interpret their findings to the people. This is a most important responsibility. Unless it is done and done well, the quality of life is likely to continue to be treated as secondary to the problems of organization for the production of goods.

Foreign Consumers and Producers of Competing Products

Although the domestic benefits of increased production-oriented agricultural research expenditures have been estimated in a number of previous studies (Arndt and Ruttan, 1977), less attention has been given to the effects on foreign consumers and producers of competing products. The following discussion is based on the assumption that increased production and lower food prices are the direct results of increased agricultural research investment.

Commercial International Trade

The initial effects to foreign consumers and producers brought about by increased agricultural research expenditures in the United States would be transmitted through commercial international trade markets. An increase in ag-food research investment in the United States will increase productivity, and hence, quantities of ag-food products to be sold in the world market. A country importing ag-food products from the United States will experience an increase in its aggregate domestic supply. For a given demand, the result would be a decrease in domestic price. Obviously, foreign consumers of imported ag-food products would benefit from lower prices. Foreign producers of competing products would be adversely affected by the lower prices. Even though foreign producers are made worse off, welfare gains to consumers (as measured by economic surplus) are greater than losses to producers (as measured by economic surplus).[7]

The net welfare effects described above are dependent upon the existence of free-trade, often not the case in current international trade markets. There is strong evidence that for many countries internal price largely is insulated from world market prices (Bredahl, Meyers and Collins, 1979). In developing countries, government intervention may exist because expanded imports resulting from lower food prices may involve risks of inadequate future food supplies if world supplies become short.

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[7] Referring to Figure 3.2, if the supply curve in a foreign country increases because of imports from the United States, foreign producers lose a surplus amount equal to area a while foreign consumers gain a surplus amount equal to area a + b. The gain in producer surplus, area c, resulting from increased imports from the United States accrues to U.S. producers.

International Food Aid

Increased agricultural output in the United States resulting from ag-food research has sometimes led to expanded international food aid programs. In terms of welfare effects[8] to foreign consumers and producers, the impact of food aid is lower agricultural prices. Producers of competing products suffer welfare losses from lower prices and consumers enjoy welfare gains from lower prices and increased food supplies. These results are dependent upon the existence of free trade, i.e., the absence of price insulation policies. Other considerations concerning the long-run impact of food aid on agricultural and economic development also may complicate the analysis of food aid programs.

International Technological Diffusion

A long-run effect of U.S. agricultural research investment involves spillovers from the international diffusion of technological innovations. Through adoption of applicable technological innovations from the United States, production practices in foreign countries are made more efficient resulting in increased supplies of ag-food products in these countries.

Consumers clearly experience a welfare gain through lower prices and increased food supplies, but producers do not unambiguously experience welfare losses as was the case with lower agricultural prices from increased imports and food aid.[9] Technological spillovers do not result in certain welfare losses to producers since the increase in supply is attributable to producers and not increased imports of food.

The transfer of agricultural technology from the developed to developing countries has been considered a major means to achieve rapid agricultural growth (Peterson and Hayami, 1977). However, much technology is not transferred easily from the developed countries because of climate and other ecological differences. In many developing countries there also may exist institutional, legal and political obstacles to innovation (Newberry, 1975). Therefore, the process of international technology transfer is highly dependent on the existing capacity for local adoption.

Researchers and Research Institutions

Agricultural research is essentially a production activity having both inputs and outputs. The principal inputs include scientific and supporting personnel, laboratory facilities, test plots, libraries and computers. The output is knowledge in numerous forms and used in a variety of ways. In its most basic form knowledge can further understanding of how biological, mechanical, economic and social systems function and how modifications can make the system function more effectively for the betterment of humanity. Knowledge of genetics, cell biology and plant and animal physiology made possible the technical progress in plant and animal breeding and nutrition. Other knowledge comes in applied forms such as new, high-yield varieties, or in forms that can be directly used by farmers, such as knowledge about the nutrient requirements of livestock and cultural practices that increase crop yields. Some of the knowledge is used by the farm supply industries in conjunction with that which is produced by their own R&D to create new, more productive inputs for agriculture, e.g., new machines, seeds or the chemicals that help control crop and livestock pests. Agricultural research produces new knowledge that in turn creates or makes possible the production of more efficient inputs for agriculture.

The research agencies of the USDA and the state agricultural experiment stations are the major public entities that produce new knowledge for the ag-food sector. The traditional rationale for public support of ag-food research has been that many firms had little capacity for conducting the research and little possibility of capturing a significant share of any gains from the results of the research. Administrators of major research agencies of the USDA and the state agricultural experiment stations have been motivated to maintain intimate relationships with their clientele and committees of Congress and state legislatures appropriating public funds for ag-food research.

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[8] Welfare effects are measured in terms of economic surpluses.

[9] Depending on the elasticities of supply and demand, producers may experience welfare gains or losses, the net effect being equal to area c - a (see Figure 3.2).

Administrators of public agricultural research agencies are motivated to optimize some combination of continuing institutional budget support and discretionary funds from state sources or from federal and private grant sources. These discretionary funds are used often to support the more basic research that has a longer-term payoff both in terms of the productivity of the applied research (Evenson, Waggoner and Ruttan, 1979) and in the prestige of the research agency. To the extent that the research efforts are successful and appropriate recognition accrues to the agency or scientist conducting the research, further increases in support in terms of institutional and discretionary funding are assured. In this sense, both public research agencies and the scientists conducting the research are direct beneficiaries of the results of the research.

Within the public research system there are two processes through which ag-food technology is produced. One is through the public sector acting "from above" in an active and coordinated fashion (that is, "demand oriented" research programs directed toward specific social or economic objectives). The second process is through the public sector responding to pressures "from below" in a relatively passive fashion (that is, "supply oriented" research programs that attempt to explore perceived opportunities for scientific or technical advance).

Much of the response of public agricultural research agencies has been through the "supply oriented" or perceived opportunity approach. Scientists perceive potential opportunities for advancement of knowledge, propose research projects to explore these opportunities and submit them for funding to the appropriate administrator or funding agency. Since there are almost unlimited opportunities that could be explored, the research administrator is faced with the decision of reconciling the interests of scientists with the legislative constraints placed on the funds in allocating them to those problems that are perceived to have top priority. Most administrators are adept in arriving at appropriate decisions, some are not. It is this process that gives rise to the notion that some agricultural research scientsists are self-serving and tend to perpetuate their own self-interests and welfare.

It is also this dichotomy between the "demand orientation" from the public sector and the "supply orientation" from the public research system that gives rise to the notion of a lack of responsiveness to the general public from the public research entities. Each of these processes is activated by different social mechanisms and each has specific characteristics in terms of the nature of technological change, bias in technological change, as well as in terms of underinvestment in public research.

No doubt, there are scientists in the ag-food research system whose efforts are perceived as relatively unproductive, just as there are in all endeavors. Once an initial pre-ordering of research programs is made based on some judgment of the importance of the problem or potential value of the research, selection of individual research projects and funding to the scientists proposing the projects must be made. A research administrator may continue to support a modest level of research activity by an unproductive scientist in order to obtain some return, however modest, from the fixed costs of salary and related benefits. In general the successes of the more productive scientists have more than compensated for the relatively unproductive scientists in the public research agencies. Furthermore, some of the important discoveries have come from individuals whose ideas had initially been rejected by their peers. There is no definitive set of criteria for judging which scientists are likely to come up with the new and evolutionary ideas. Advances in basic knowledge are rather sporadic and unpredictable.

Another erroneous, general notion is that agricultural research scientists are relatively overpaid, and rising salary cost for scientists is the principal component of the increase in expenditures required to support public agricultural research. Data from 12 to 26 state agricultural experiment stations and SEA/AR, USDA over the 1973-1979 period do not support such a contention. An index of research input prices for manpower and non-manpower categories is shown in Table 3.3. The average annual rate of increase in the non-manpower category (i.e., air and auto travel, office and laboratory supplies, construction and equipment, communications and utilities and an "all other expense" category) is considerably greater than for the manpower category. Salary increases vary widely among individuals, but in general the average salary increase for agricultural researchers

Table 3.3 Index of Research Input Prices in the SAES and SEA/AR Area and Laboratory Locations in the Northeast and Western Regions.

Fiscal Year	Manpower components	Annual Change (%)	Non-manpower components	Annual Change (%)
		State agricultural experiment stations		
1973-74	83.7	—	77.3	—
1974-75	86.7	3.6	87.9	13.7
1975-76	93.2	7.5	94.2	7.2
1976-77	100.0	7.3	100.0	6.2
1977-78	104.7	4.7	106.2	6.2
1978-79	113.1	8.0	115.1	8.4
1979-80	120.2	6.3	132.7	15.3
(Average 1973-79)		(6.2)		(9.5)
		SEA/AR Northeast and Western locations		
1973-74	85.9	—	76.4	--
1974-75	90.2	5.0	86.9	13.7
1975-76	95.2	5.5	93.4	7.5
1976-77	100.0	5.0	100.0	7.1
1977-78	107.1	7.1	107.1	7.1
1978-79	113.0	5.5	118.1	10.3
1979-80	120.9	7.0	135.9	15.1
(Average 1973-79)		(5.9)		(10.1)

Source: Murphy and Kaldor (1980); Eddleman (1980).

in the SAES's and the USDA research agencies has not kept pace with inflation in other research expenditure components since 1973.

Murphy and Kaldor provided information on annual salary compensation for research scientists and four other personnel categories in the SAES's. These data are presented in Table 3.4. Research scientists' salaries increased at the slowest annual rate (5.3%), whereas research administrators in the SAES's experienced the highest rate of increase in annual salary (10.6%). The low rate of increase in average annual research scientists' compensation is due mainly to salary and fringe benefits being administered by Congress and the state legislatures. In this sense, the agricultural researcher has, in effect, subsidized other segments of the USA economy. This most valuable component of ag-food research has contributed least to the rising costs of performing ag-food research, both within the SAES's and the USDA.

Table 3.4. Sample Average Annual Cost and Index of Manpower Components in SAES by Employment Category, 1973-1978.

Year	Number of Stations Reporting	Scientists	Professional	Technical	Clerical	Administrative
		---Annual salary, $ per year---				
1973	12	22,050	8,561	7,624	7,284	21,334
1974	13	22,746	9,031	8,125	7,503	22,169
1975	14	24,550	10,353	8,467	8,490	22,318
1976	16	25,690	11,180	9,458	9,027	27,359
1977	23	26,662	11,826	10,241	9,725	28,396
1978	25	28,552	12,769	11,041	9,987	35,420
		---Index of manpower costs, 1976=100---				
1973	12	85.8	76.6	80.6	80.7	80.0
1974	13	88.5	80.8	85.9	83.1	81.0
1975	14	95.6	92.6	89.5	94.1	81.6
1976	16	100.0	100.0	100.0	100.0	100.0
1977	23	103.8	105.8	108.3	107.7	103.7
1978	25	111.1	114.2	116.7	110.6	129.5
		---Average annual rate of manpower cost increase, %---				
1973-74		3.1	5.5	6.6	3.0	1.2
1974-75		8.0	14.6	4.2	13.2	0.7
1975-76		4.6	8.0	11.7	6.3	22.5
1976-77		3.8	5.8	8.3	7.7	3.7
1977-78		7.0	7.9	7.8	2.7	24.9
(1973-78)		5.3	8.4	7.7	6.6	10.6

Source: Computed from Murphy and Kaldor (1980).

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Section IV

BENEFITS FROM AG-FOOD RESEARCH RELATED TO FUNDING SOURCES

This section addresses the issue of benefits stemming from ag-food research as related to funding sources and levels. Several ramifications of this issue include: 1) the tax incidence and flow of benefits by income groups; 2) the equity of the tax incidence and flow of benefits from federal and individual state funds; 3) costs to the public and private sectors and the benefits accruing to each; and 4) costs and benefits from direct funding sources.

Ag-Food Research Costs and Benefits Associated with Income Classes

The major sources of public support for ag-food research are federal and state appropriations funded by tax revenues. In order to compare benefits and costs, taxes applied to ag-food research were distributed over income classes. Data on the distribution of the effective tax rate among various income categories are limited. Some of the more recent work on tax categories involved data for 1966 (Pechman and Okner, 1974). A more recent analysis that focused only on personal income and general sales taxes will be used to allocate agricultural research expenditures among various income groups on the basis of taxes paid (U.S. Advisory Commission on Intergovernmental Relations, 1974). The effective tax rate for the federal personal income tax among income classes was used to allocate federal agricultural research expenditures among families of different incomes. The distributions of state personal income and general sales tax rates were used to allocate state agricultural research expenditures.

The total costs in 1974 of production-oriented research funded by federal and state sources were \$330.8 and \$243.7 million, respectively (Budget of the U.S. Government; USDA, SEA, Inventory of Agricultural Research; and U.S. Dept. of the Treasury). Estimates of taxes paid as a percent of average family income were used to distribute federal and state taxes over income classes. The percent of taxes paid by each income class was used to determine the amount of taxes collected by federal and state governments to support ag-food research.

The cost of ag-food research, as measured by production-oriented research expenditures, is reported on a household basis (Table 4.1). Total agricultural research costs per household ranged from \$1.31 for the lowest income class, under \$5,000 to \$25.60 for the highest, over \$20,000. While both benefits and costs increase with the level of income, tax incidence increases at a faster rate. Therefore, the benefit-cost ratio is highest in the low-income category. The benefit-cost ratio declined from 12.37 for low-income families to 1.20 for high-income families. Both benefits and costs of agricultural research expenditures tend to redistribute income from higher- to lower-income families. However, even those families in the highest income class receive net benefits from research investment on agricultural productivity.

State Government Funding and Flow of Benefits

The action of one state government can exert either beneficial or harmful impacts on residents of other states without accompanying compensation, and ag-food research financed by one state may benefit the residents of other states (positive externality).[1] For example, an improved crop variety developed in one state may be adopted in neighboring states to increase yields and total production. However, in some cases an action by a

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[1] Benefits from scientific or technical progress, originating from a private firm or in the public sector, that flow to other firms or consumers without compensation to the firm or public sector component originating the research are called externalities. Obviously, these effects may have either positive or negative impaction.

Table 4.1. Relationship of Costs and Benefits of Agricultural Research to Family Income.

Income Class	Average Family Income[a]	Average Benefits per family[b]	Federal Taxes for Agricultural Research per family[c]	State Taxes for Agricultural Research per family[d]	Total Taxes for Agricultural Research per family[e]	Benefit-Cost Ratio[f]
--Dollars--						
Under 5,000	3,981	16.20	.43	.88	1.31	12.37
5,000-8,000	7,922	19.06	1.77	2.05	3.82	4.99
8,000-12,000	10,528	20.63	3.19	2.85	6.04	3.42
12,000-15,000	13,458	22.13	5.29	3.97	9.26	2.39
15,000-20,000	17,371	25.91	8.40	5.59	13.99	1.85
Over 20,000	28,953	30.74	15.78	9.82	25.60	1.20

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[a] Source: U.S. Dept. of Commerce, Bureau of the Census, Current Population Reports, Series P-60, No. 101, "Money Income in 1974 of Families and Persons in the U.S.," U.S. Government Printing Office, Washington, D.C., 1976.

[b] Expressed in present value. See Table 3.1 for details of calculation procedure.

[c] Production-oriented research expenditures for Agricultural Research Service, Economic Research Service and the Federal Government's Share of State Agricultural Experiment Stations are allocated among income groups according to the distribution of Federal personal income taxes (U.S. Advisory Commission on Intergovernmental Relations, 1974).

[d] State funded production-oriented agricultural research expenditures are allocated among income groups according to the distribution of state personal income and general sales taxes (U.S. Advisory Commission on Intergovernmental Relations, 1974).

[e] Summation of Federal and State taxes for agricultural research per family.

[f] Average benefits from agricultural research expenditures per family divided by total taxes for agricultural research per family.

state may adversely affect residents of another state (negative externality). Producers in regions other than where the improved crop variety was developed and where that particular variety would not be suitable for adoption might experience lower prices, ceteris paribus, as the result of increased aggregate production.

The principal source of agricultural research externalities is evident: state boundaries do not coincide with homogenous agricultural production regions. Research projects in one state, that are addressed to specific local problems, likely will produce results applicable to other states within the same homogenous production region. Even applied research focused on a specific local problem may be adapted for more general purposes to help meet the needs of producers in other regions. Furthermore, basic research is disseminated without regard to geographic boundaries.

Externalities or spillovers complicate the problem of determining optimal levels of public research expenditures. With positive net spillovers, the level of research expenditures, financed at the state level, is likely to be lower than that which would be considered desirable from a national perspective.

If the level of research activity in each state is based on benefits to the state rather than to society, potential inefficiencies arise. Externalities must be accounted for and internalized if research activity levels are to be determined efficiently. However, there is no self-correcting mechanism to insure efficient levels of agricultural research.

The existence of an externality does not in itself merit corrective action. It may be that a greater loss in welfare will occur from internalizing an externality through a resource reallocation than the gain in welfare deriving from such an action (Coase, 1960). For example, the cost of internalizing a positive externality, where social benefits exceed internal benefits to a particular state, may be greater than the total benefits of the externality itself. On the other hand, the cost of internalizing an externality through a resource reallocation in many cases may warrant a policy adjustment. This would be true if the cost of internalization is less than the total benefits and cost is needed to justify such an action. Therefore, estimation of the magnitude of agricultural research externalities and the cost of internalizing these externalities are required in order to justify policy adjustments relating to these externalities.

Spillover benefits generated by state A which accrue to the residents of state B generally are not accounted for by state A policymakers. The earlier argument concerning neglect of these externalities has been that state A will provide a smaller level of research expenditures than would be efficient from society's perspective. Given the possibility of negotiation between states, state B may find it advantageous to pay A to increase its level of research activities. Such a subsidy will reduce A's research costs and lead to a higher level of research activities. The negotiation process likely will be complicated by the fact that spillovers flow in both directions between the two states. Furthermore, the outcome will depend on the relative bargaining strength of the two states and will not lead necessarily to an efficient solution to the externality problem (Musgrave and Musgrave, 1973).

In those cases in which only a small number of decision-making units are involved, voluntary action among the interested parties could be used in such a manner that all benefits are considered (Oates, 1972). For example, if only a few states produce a given commodity, then one of the states might conduct the research for this commodity with the research effort supported by the other states. However, attempting to coordinate these activities involves decision-making costs that include the value of time, effort and direct outlays related to the bargaining process. These costs increase rapidly with the number of decision-making units involved as a result of having to obtain agreement among more parties (Buchanan and Tullock, 1962). For those cases in which externalities from agricultural research affect a large number of decision-making units, total decision-making costs of effective coordinated action likely are to be quite large. When the impact on consumers is considered, then a large number of states would be concerned with almost all aspects of agricultural research.

Federal Government Funding Related to Flow of Benefits

Public goods with significant externalities may be classified as either national or quasi-national public goods. A national public good that is consumed equally by all residents (e.g., national defense), may be provided more efficiently by the federal government than by lower-level governments. Quasi-national public goods, on the other hand, are consumed on a less comprehensive basis throughout the nation. The mere existence of externalities associated with these public goods does not mean necessarily that they should be provided solely by the federal government since a highly centralized structure allows little opportunity for differences in expenditure patterns. Also, the federal government will not be necessarily more efficient than lower-level governments in providing quasi-national public goods. However, the existence of significant externalities suggests a possible need for intergovernmental fiscal coordination.

Agricultural research serves as an example of a quasi-national public good. Financing agricultural research at the state level produces benefits that are consumed by the state's residents, but in addition benefits also pass to other states and nations in the form of externalities. While it can be produced at either the federal or state level of government, the presence of externalities indicates a need for the coordination of research among various states.

Partial funding by the federal government affords one solution to attaining the nationally desired level of regional research expenditures. An often used technique to increase state expenditures for governmental services is the matching grant, in which the recipient state government is required to match federal funds with funds from its own sources according to some specified formula. Such a formula should be based on the relative importance of external to internal benefits. The objective of matching grants is to internalize the externalities or spillovers from regionally financed research expenditures. While some federal grants to states for ag-food research require matching funds, most states invest more in ag-food research than just that required to match grants. However, the matching grant program can serve as a standard of evaluation for the current system of federal grants for agricultural research.

The formula for matching funding should be based on the relative importance of external and internal benefits. If these grant programs are properly designed, they should direct state expenditures toward levels considered optimal from a societal perspective rather than a state perspective by financing the cost of external benefits of internalizing the externalities. The ratio of spillovers to internal benefits could be used to determine the federal government's share of research expenditures. In this sense, the federal government would match state expenditures for research that had external spillover effects to other states or regions.

The development of an appropriate matching grant program obviously requires identification and quantification of state benefits and spillovers from agricultural research expenditures. There have been some recent developments concerning the measurement of spillovers. Evenson, et al. (1979) estimated that, on the average, 55% of the change in productivity attributed to technology-oriented research was realized within the state conducting the research. The remaining 45% was realized in other states. Interregional spillovers of the benefits from ag-food research were estimated by White and Havlicek (1980), (Table 4.2). These estimates indicate that the aggregate ratio of spillovers to regional benefits is 1.73. The Northeast and the Appalachian Regions have the lowest ratio of spillovers to regional benefits. Four regions (Lake States, Corn Belt, Delta and Southern Plains) have spillover-to-regional benefit ratios higher than two to one.

The ratio of federal-to-state expenditures[2] for ag-food research and extension can be compared with the ratio of spillovers to regional benefits to determine whether the federal government actually financed the spillovers (Table 4.2). These results indicate that the federal government financed all of the spillovers in only three regions

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[2] Federal expenditures are not limited to those funds going to the state agricultural experiment stations and cooperative extension services under formula and grant programs; they also include the funding of agricultural research in each region through the USDA agricultural research agencies of SEA/AR, USDA/ESCS and USDA/SCS.

Table 4.2. Regional Estimates of External-to-Internal Ratios Related to Benefits and Funding of Production-Oriented Agricultural Research and Extension.

Region	Ratio of Spillovers to Regional Benefits	Ratio of Federal-State Expenditures[a]
Northeast	1.31	0.97
Lake States	2.73	1.10
Corn Belt	2.04	1.25
Northern Plains	1.40	1.63
Appalachian	1.19	1.60
Southeast	1.40	1.37
Delta	2.48	1.80
Southern Plains	2.80	2.10
Mountain	1.60	2.35
Pacific	1.89	0.90
Aggregate	1.73	1.38

[a] Includes federal funding of production-oriented agricultural research and extension in each region through SEA/CR, SEA/AR, SEA/EXT, USDA/ESCS, and USDA/SCS relative to state expenditures for agricultural research and extension in each region.

Source: Fred C. White and Joseph Havlicek, Jr., "Interregional Spillover of Agricultural Research Results and Intergovernmental Finance," Paper presented at Symposium on Methodology for Evaluation of Agricultural Research, Minneapolis, Minnesota, May 12-13, 1980.

(Northern Plains, Appalachian and Mountain Regions). In aggregate, the ratio of federal-to-state expenditures is only 1.38 compared to 1.73 for the ratio of spillovers to regional benefits. Thus, the federal government's contribution to production-oriented ag-food research and extension should be increased 25% to align regional funding with regional benefits, on the average. Several regions would require a greater increase in federal expenditures to yield an equitable distribution across all regions.

Private Sector Funding Related to Flow of Benefits

One continuing issue is who captures the benefits from public sector and private sector research. Presumably the issue relates to the question of whether a particular problem area should be addressed through public research if the gains from the research are embodied in private firms' products. In general, there are spillovers or indirect benefits from public sector research to the private sector and from private sector research to society. If the benefits from the results of the research can be captured by the private sector, then there is an incentive for private firms to invest in the R&D activities.

Research activities are distinguishable in terms of patent enforceability of the product, technique or process, economic life of the technique or process, technological versus pecuniary effects and the ability of rivals to imitate the research and development process. These characteristics determine whether the net benefits of the R&D activities can be captured by the private sector. To the extent that such benefits can be captured (and adequate incentives exist for the private sector to make the R&D investments), public sector involvement in such research and development activities would be a form of subsidy to private firms.

The private sector may invest in research and development activities in which spillover or indirect benefits accrue to society. No specific studies have been made for the agricultural input or food processing industries. Studies by Mansfield, et al. (1977), Terleckyj (1974) and Griliches (1977) of the distribution of gains from private R&D in manufacturing and nonmanufacturing industries indicate that the spillover effects are at least as large as the direct benefits going to the firms conducting the R&D. Thus, the social returns tend to be roughly double that of private returns to the investment. In this regard, substantial social benefits are derived from private industry investments in R&D activities.

The USDA (1979) assessment of postharvest technology research identified four distinguishing characterisitcs of private sector research in food processing, handling and marketing. These were: 1) most private sector research tends to be focused on short-term applied problems for which there is expectation of an acceptable return on the research investment; 2) longer-term basic inquiry into how biological, economic and social systems function would not be picked up by the private research sector if it should be dropped by the public research agencies; 3) even though there may exist substantial social benefits from private research activities through spillover effects, private industry generally is not concerned with the concepts of consumer surplus or net social benefits from their research endeavors; and 4) most private firms are reluctant to reveal knowledge that might cause existing technologies or processes to become obsolete prior to extracting the flow of economic returns from past investments in these techniques. Thus, there is incentive to delay publication of knowledge possessing this potential impact even if the research might have been carried out partially under the auspices of public funding.

Public sector support for basic research generally benefits both society and the private sector. Since the results of basic research are difficult to internalize to any particular private firm without public support, underinvestment in this type of research activity would result. However, in the case of applied and developmental research the appropriate mix of public and private research investments becomes an important issue. The private sector will stand to benefit from public investments in those research outputs that are embodied in private sector products. Examples include chemical research activities, mechanical research activities and development of seed varieties. It is in these areas that much of the R&D responsibility has been assumed by the private sector, but public research activities also are maintained. The public R&D may be justified on at least three grounds: 1) due to the spillover effects, substantial social benefits are derived from the mixture of public and private research; 2) in the absence of public sector support, the direction of the research might tend to be biased strongly toward proprietary mechanical and chemical technologies; and 3) for those situations whereby private research might have a detrimental effect on the structure of the industry (making a competitive structure noncompetitive, or a noncompetitive structure still more imperfect), a mix of public and private research may serve to preserve competition and/or reduce the amount of concentration. The importance of this last basis for public investments in the research is that most competitive industries provide a larger quantity of the product at a lower cost to consumers than would be expected from an uncontrolled monopolistic industry.

For biological research activities, due to the ease of imitation and the lack of patent enforceability, it is likely that the private sector would substantially underinvest in the R&D. Thus, much of the biological research is supported from the public sector, even in those areas where there are substantial inducements for product development by the private sector. Few seed companies, for example, carry out much research in plant pathology, plant physiology, genetics, crop management systems or farm management. But since the outputs of the public sector research is a public good, they are available to large and small input suppliers alike. Because of the difficulty of patenting hybrids by public research institutions, small seed companies have been able to exist along with large firms. Thus, it has been generally in the best interest of society to support public investments in these types of research activities since the social benefits would outweigh the costs incurred from increased concentration in the industry. A recent decision by the U.S. Supreme Court related to patentability of biological research requires careful re-examination of current policies of the public ag-food research agencies.

Direct Funding Sources (e.g., Checkoff Funds) Related to Benefits

The same general relationships between private sector funding and recipients of the benefits from agricultural research exist for direct funding arrangements. Producer checkoff funding may be viewed as a collection of private firms pursuing their own best interests by collectively supporting public research activities. It probably is true that less control is exercised over the specific projects to be funded as would occur with a private firm. But the usual process is for the recipient public research agency to put forth a portfolio of potential research projects for which the funds could be used. Then a governing board (often labelled a specific commodity research promotion board) selects from among the portfolio those projects that best coincide with their constituency's interest within available funds. The public research administrator then "awards" the funds to those projects and scientists proposing the specific R&D activities.

Promotion funds tend to focus the research toward short-term, applied R&D activities that hold promise for benefiting the clientele providing the funds. Heavy reliance on this type of funding source for public research support would tend to bias the direction of the research toward those techniques most beneficial to the group providing the funds.

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Section V

SOCIETAL BENEFITS FROM RESEARCH

This section addresses the direct benefits accruing to society (the consuming populace of the USA) with supporting empirical evidence. Societal benefits accruing from ag-food research are compared further with other federal R&D programs, and with R&D activities in the private sector. Implications are drawn also with respect to the impact of ag-food productivity on the cost of other federal programs.

Direct Benefits Accruing from Ag-Food Research

Most evaluations of ag-food research indicate an internal rate of return that is quite favorable. The internal rate of return can be defined as that discount rate which equates the present value of the expected cash outflows (costs) with the present value of the inflows (benefits).

With respect to economic efficiency, the acceptance criterion for a research proposal is based on the relationship of the internal rate of return to a required rate of return. For a firm the required rate might be the cost of capital, while for the public sector the required rate might be some long-term interest rate or social discount rate. If the internal rate of return is higher than the required rate, then the investment should be undertaken.

Evaluations that measure the contribution of past research investments on observed increases in agricultural productivity are used to identify trends in rates of return and thus help policymakers allocate research funds. Two ex post evaluation procedures commonly are used. The index number method compares the consumer and producer surplus changes with the costs of the research. The regression method considers research as an input and, through a production function, shows how much these expenditures contribute to output. The index number method compares total benefits to total costs, and leads to an average rate of return. The regression method that follows leads to a marginal internal rate of return by comparing the benefits from the last dollar spent on research. A marginal rate is more useful to policymakers who must decide how to make incremental changes efficiently.

Limitations of the Alternative Approaches

Both methods of evaluation use a partial equilibrium approach, and therefore, are unable to measure the benefits and losses present in other parts of the economy. The changes in the labor market usually are not considered. However, an attempt was made by Schmitz and Seckler (1970) to account for workers displaced by tomato harvesters. Many of the displaced inputs, labor or capital, can be used to produce other commodities. The research spillovers from neighboring regions with similar research only recently have been considered (Evenson, Waggoner and Ruttan, 1979; White and Havlicek, 1979; Sundquist, Cheng and Norton, 1980). Agricultural commodities are traded and the change in consumption of close substitutes or complements from a price decrease due to new technology also should be considered.

As with any economic analysis, problems exist with getting accurate data that properly represent the variable. The costs of research should include the farmer's cost of discovering and implementing the new technology and the costs of administering the research. For a particular commodity these costs may be hard to measure. Another cost often is ignored because research evaluation studies fail to account for basic science contributions to successful applied research innovations (Rausser, et al., 1980). Many technological innovations have occurred shortly after some particular breakthrough in basic research. Yet the costs of basic research are not included in measuring the rates of return on agricultural research, because it is practically impossible to determine the contribution of basic research to technological innovations. However, it appears that the estimated rates of return overstate the true rates for failure to account for basic research investments, as well as other omitted costs.

Rate of Return Estimates

Several studies that have empirically estimated rates of return on agricultural research investment are summarized in Table 5.1. For aggregate investment, rate-of-return estimates are predominately in the range of 30-40%. However, the lowest estimate for this category is 23.5% compared to the highest estimate of 100%. Some of the returns on individual commodities are outside this latter range. The most obvious conclusion from these consistently high rates of return is that agricultural research is very profitable.

Four of the studies show that returns to agricultural research tended to be higher in the early part of the century and have declined slightly during the more recent time periods. A likely explanation is that now there are fewer opportunities to substitute new technology embodied in capital for labor. However, the rates of return in the most recent periods are still quite high. Davis (1979) noted that since 1964 the marginal internal rate of return has remained surprisingly constant and may have stopped declining.

Interpretation of the Results

The empirical estimates of rates of return on agricultural research consistently appear to be high. Research administrators point to these returns with pride indicating that public investment in agricultural research has been a successful undertaking. However, the high returns are evident of a problem related to inefficiency. Economic efficiency calls for investment funds to be allocated in such a manner that the marginal returns in all categories are the same. The high rate of return on agricultural research indicates underinvestment by the public sector. In other words, additional resources should be allocated to agricultural research in order to bring its rate of return in line with the returns from other public investments. The following discussion indicates why public investment has been limited to the extent to generate such high rates of return.

At a recent symposium on Methodology for Evaluation of Agricultural Research, Minneapolis, Minn., May 1980, a government official said "The government is not in business to make money." While this statement may represent the sentiments of many legislators and other government officials as related to the high returns on agricultural research investment, it warrants further elaboration and interpretation. Economic growth traditionally has been fostered in this country as a means to progress. Furthermore, economic efficiency is a means to achieve economic growth and it would be improper to ignore the rate-of-return estimates as an indicator of economic efficiency. Complications arise, however, as society attempts to achieve a variety of goals.

The social optimum actually may involve a trade-off between goals. For example, the public sector might choose to limit expenditures in a particular category below the level called for by economic efficiency if such expenditures would affect adversely the distribution of income. This particular relationship is commonly referred to as the trade-off between efficiency and equity. Section III of this report has dealt with equity issues by identifying the impact of agricultural research on various groups---farmers, labor and input suppliers, marketing firms, consumers and the general public. A general conclusion from that section is that consumers and the public in general are major beneficiaries of agricultural research. Furthermore, Section IV of this report examined issues related to income distribution through benefits and costs of agricultural research.

Agricultural research expenditures over the last half century may have been limited by policymakers' perception of excess capacity in agriculture. Congress continually battled with the problem of depressed farm prices, caused by excess production at prices considered to be socially acceptable. Policymakers were probably aware of the dilemma that if research investment increased supplies, then costs of maintaining farm prices would increase. The problem facing policymakers in this area now revolves around what will happen to agricultural supplies and farm prices in the future. If excess capacity is projected to continue into the next century, policymakers will tend to limit agricultural research expenditures. However, if increased agricultural productivity will be needed to furnish adequate supplies for domestic consumers and for foreign trade, a greater level of research investment would be warranted.

Policymakers may tend to limit agricultural research expenditures because of the uncertainties about future benefits from agricultural research. After all, the estimated rates of return are based on historical relationships that may not hold in the future.

Table 5.1. Empirical Rate of Return Estimates for Agricultural Research Investment.

Study	Commodity	Time Period	Internal Rate of Return (Percent)
Index Number Approach			
Griliches (1958)	Hybrid Corn	1940-55	35-40
Griliches (1958)	Hybrid Sorghum	1940-57	20
Peterson (1967)	Poultry	1915-60	21-25
Schmitz and Seckler (1970)	Tomato Harvester	1958-67	37-46
			16-28[a]
Peterson and Fitzharris (1975)	Aggregate	1937-42	50
		1947-57	51
		1957-62	49
		1967-72	34
Regression Analysis Approach			
Griliches (1964)	Aggregate	1949-59	35-40
Peterson (1966)	Poultry	1915-60	21
Evenson (1968)	Aggregate	1949-59	47
Lu and Cline (1977)	Aggregate	1938-48	30.5
		1949-59	27.5
		1959-69	25.5
		1969-72	23.5
Knutson (1977)	Aggregate	1939-48	49.7
		1949-58	47.4
		1959-68	39.4
		1969-72	35.5
White, Havlicek and Otto (1978)	Aggregate	1929-41	36.5[b]
		1942-57	32.2[b]
		1958-77	27.8[b]
Davis (1979)	Aggregate	1949	100[c]
		1954	79[c]
		1959	66[c]
		1964	37[c]
		1969	37[c]
		1974	37[c]
Bredahl and Peterson (1976)	Cash Grains	1969	36
	Poultry	1969	37
	Dairy	1969	46
	Livestock	1969	47
Norton (1980)	Cash Grains	1974	85[d]
	Poultry	1974	46[d]
	Dairy	1974	51[d]
	Livestock	1974	88[d]

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[a] Estimates account for compensation of displaced workers.

[b] The estimates were reduced by one third to correct for the omission of private research.

[c] Estimates are based on cross section using real output and deflated research. Estimates are high because extension is omitted and a small adjustment for private research is used. If adjustments are made these rates would be around 20% for 1964-79.

[d] These estimates correspond to the mean lags used by Bredahl and Peterson (1976).

Even though expected returns may be high, policymakers may perceive a wide confidence interval around the expected returns believing that they are not measured precisely. Although there is some controversy in this area, there does appear to be widespread support for the proposition that the public sector should invest on the basis of expected returns and ignore risk factors. However, policymakers may contend that expected returns are not measured accurately enough to guide decisions on the optimal level of public investment in ag-food research.

Social Benefits from Other Federal Research and Development Programs and Development Activities of Private Industry

Considerable work has been carried out in the 1970s by economists, engineers and other scientists to evaluate industrial R&D projects. These studies have considered both private R&D and federally sponsored R&D projects within private manufacturing and nonmanufacturing industries. Little effort has been undertaken to evaluate the social and economic benefits from other types of federally sponsored R&D such as that carried out by the departments of health, education and commerce.

In this section we review briefly several recent studies of R&D returns to private and public investments in industry and summarize some of the evaluations of scientific productivity based on publications and citations analysis.

Industrial R and D Projects

One study examined the returns to NASA R&D expenditures versus "other" R&D expenditures at the aggregate (total GNP) level over a 14 to 18 year period (Chase Econometrics Associates, 1975). Returns of 40% per year in perpetuity were estimated for NASA R&D, more than twice the returns to "all other" R&D spending. The U.S. General Accounting Office (1977) and Griliches (1979) have questioned the results of this study on the basis of: 1) its assumptions and the various data adjustments made by the investigators; 2) the use of aggregate total factor productivity growth (total GNP) as the dependent variable to be explained rather than factor productivity growth in various sectors of the economy; 3) the relatively short time series of data used in the analysis; and 4) the use of the same time lag structure for NASA R&D and "all other" R&D spending. Results from other studies, using microdata sets, are in sharp conflict with the results obtained from this study.

A series of studies by Terleckyj (1974, 1975 and 1977) examined the relationship between rates of total factor productivity growth (1948-1966) for 20 to 33 two-digit industries and a number of measures of R&D intensity ratios and other non R&D variables, such as percent of sales to the private sector, degree of union membership, annual rate of cyclical change in output and ratio of investment in plant and equipment to value added. Two types of R&D expenditures were considered--privately financed R&D and government financed R&D. The results showed: 1) a strong direct effect by privately financed R&D on growth of factor productivity; 2) no discernible effect by government financed R&D; 3) a significant influence of "borrowed" R&D from "other" industries, weighted in proportion to the borrowing industry's purchases from them, on productivity growth of the borrowing industry; and 4) considerable differences in the effects of R&D expenditures on growth of productivity in manufacturing and nonmanufacturing industries.

Productivity in a given industry can increase indirectly through purchase of R&D-intensive capital or intermediate goods from other industries. Examples include computers for use in banking and insurance companies, fertilizers for use in agriculture or prefabricated structures for use in the construction industry. These inputs contribute substantially to productivity of the industries using them which do not undertake any significant R&D of their own. These indirect or "spillover" effects are attributed to R&D through the purchase of inputs by one industry from other industries. Terleckyj's (1974) results indicate a 30% direct rate of return and an 80% indirect rate of return for privately financed R&D in manufacturing. He estimated a zero direct but large indirect (187%) rate of return for R&D expenditures in nonmanufacturing industries. He also found that government financed research (except in agriculture) had no direct effect on the productivity of the industries conducting it. There was evidence that the indirect or spillover effect of government financed R&D embodied in purchased inputs had little or no impact on the growth of output in the purchasing industries.

Terleckyj's results are higher than the estimates obtained by Griliches (1977) using data (1957-1966) from 883 large U.S. corporations. He obtained an average estimate of the direct rate of return to R&D of 19% among all industries. The indirect rate of return was estimated to be around 20%. Griliches also found that industries having a high share of government financed R&D had lower rates of return to R&D.

In another study Mansfield, et al. (1977) estimated private and social rates of return for 17 industries, finding a median private rate of return of 25% and a median social rate of 56%, which suggests a spillover or indirect benefit of about 30%.

Most of these recent studies confirm previous findings of high rates of return on privately financed R&D during the 1950s and 1960s. The studies indicated a direct rate of return to R&D of about 25 to 30%, and that the indirect or spillover effects of R&D were at least as important as their direct effects. There was some evidence, mostly negative, on the direct and indirect contribution to productivity growth of government financed R&D, particularly in the manufacturing industries. In nonmanufacturing industries, the evidence of no indirect effect of government financed R&D was not established clearly.

The direct rate of return to R&D varied among industries. Griliches (1977) found rates of return of 93 to 103% for the chemicals, motor vehicles and the "all other industry" groups; and 2 to 3% for electrical equipment and aircraft and missiles. The low rates in these two industries are attributed to the depressing effects of specificity (and nonmarket orientation) of federally supported R&D in these industries.

Mansfield, et al. (1977) also found that the social and private rates of return vary greatly for different innovations. The social rate of return generally exceeds the private rate, and in about 30% of the 17 innovations the private rate of return was so low that no firm, with the advantage of hindsight, would have invested in the innovation. However, the social rate of return from these innovations was fairly high (Table 5.2).

All these studies used data from the 1950s and 1960s. Results indicate that the average social rate of return from investments in new technology in industry has tended to be relatively high, from 30 to 50% annually. Moreover, the marginal social rate of return also seems to be high, generally at least 30%.

In a recent study, Griliches (1980) finds that the contribution of R&D to total factor productivity in 39 U.S. manufacturing sectors is zero, or at least cannot be discerned from the data during the 1969-1977 period. In contrast, during the 1959-68 period results for R&D expenditures were consistent with those he obtained previously using data from the sample of 883 firms. He attributes his lack of findings for the 1970s period to "data difficulties and the turmoil of the times" rather than a lack of investment in R&D or decline in R&D productivity. In particular, much of the R&D spent during this period was on health and environmental enhancement that do not contribute to the national product accounts. Further, the large energy price increases, fluctuations in capacity utilization and uncertainty about future absolute and relative prices may have forced many firms away from their long-run production frontiers. Thus, the data are not reflective of R&D investments whose purpose is to shift this frontier outward.

Concepts such as rates of return to innovation and diffusion of innovation provide the basis for analysis of the economic growth effects of R&D. The noneconomic benefits to the public from R&D activities present an especially difficult problem. They generally have not yet been defined adequately, and no satisfactory method of measurement currently exists. One recent study by Schachter (1977) has attempted to show that returns to R&D can be identified as a component not only of economic growth but also of "social" growth. Estimates were made of the increments to life expectancy in the U.S. during 1940-1970 that can be traced to specific innovations resulting from biomedical research.

Scientific Literature and Citations

It is impossible to quantify precisely the results of much federally sponsored research or determine the incremental advancement of knowledge provided by an increase in R&D funding. However, scientific literature and citations analysis contribute information on R&D outputs.

Table 5.2. Social and Private Rates of Return from Investment in Seventeen Innovations.

Innovation	Rate of Return (percent) Social	Rate of Return (percent) Private
Primary metals innovation	17	18
Machine tool innovation	83	35
Component for control system	29	7
Construction material	96	9
Drilling material	54	16
Drafting innovation	92	47
Paper innovation	82	42
Thread innovation	307	27
Door control innovation	27	37
New electronic device	Negative	Negative
Chemical product innovation	71	9
Chemical process innovation	32	25
Chemical process innovation	13	4
Major chemical process innovation	56	31
Household cleaning device	209	214
Stain remover	116	4
Dishwashing liquid	45	46
(Median rate of return)	(56)	(25)

Source: Mansfield, et al. (1977).

The publication of scientific and technical findings is one of the more direct forms of R&D output. The NSF Science Indicators for 1978 show that the U.S. proportion of the world's influential journal literature for all fields of inquiry remained at about 38 to 39% during 1973-1977 (Table 5.3). The U.S. proportion of publications declined in the fields of biology, chemistry, physics, earth and space sciences, engineering and technology, psychology and mathematics, with the sharpest drops occurring in mathematics and biology. Only the fields of clinical medicine and biomedicine maintained their 1973 proportion in 1977. Agricultural and food sciences are among subfields included in the biology field. No detailed data were provided on changes in the relative proportions for the subfields.

Since the U.S. provides about two-fifths of the world's influential scientific and technical literature, it follows that U.S. literature would be cited highly. Relative citation ratios normalize for this factor and are used as an influence measure on the assumption that the most significant literature will be cited more frequently than the routine literature. U.S. scientific and technical articles were cited 30% more than would be expected by their share of the world's literature in 1977, indicating that U.S. R&D is relatively influential in world science (Science Indicators, 1978). The most influential U.S. fields were chemistry and physics and the least influential U.S. fields were biology,

Table 5.3. U.S. Proportion of the World's Articles[a], 1973-1977.

Field	Percent 1973	1975	1977
All fields	39	38	38
Clinical medicine	43	43	43
Biomedicine	39	39	39
Biology	46	45	42
Chemistry	23	22	22
Physics	33	32	30
Earth and space sciences	47	44	45
Engineering and technology	42	41	40
Psychology	76	75	74
Mathematics	48	44	41

[a] As a percentage of the 271,000 to 279,000 articles, notes and reviews per year from over 2,100 of the influential journals of the Science Citation Index Corporate Tapes of the Institute for Scientific Information.

Source: National Science Board, Science Indicators 1978, National Science Foundation, Washington, D.C., 1979, p. 15.

psychology and engineering, all of which had an influence in the foreign literature at least proportional to their share of the world's publications.

The relationship between NIH funding and biomedical publication output for 229 major NIH supported institutions, accounting for about 90% of total NIH research funding going to these institutions between 1965 and 1972, was investigated by Frame and Narin (1976). A high degree of correlation ($r = 0.95$) was found between the amount of NIH funding and the number of biomedical publications for 132 U.S. universities. An output of approximately four and one-half publications was associated typically with increased NIH funding levels of $100,000 compared with about three and one-half publications per $100,000 of NIH funding in large hospitals. Clearly, NIH plays a dominant role in supporting the biomedical research performed at U.S. research institutions, and the quantity of research publications produced by universities and hospitals strongly reflects the magnitude of this support.

Scientific literature indicators are only proxy measures for R&D productivity and output, and as such, have limitations. Restraints on the number of journals available to a field of scientific inquiry, space available per journal, publication refereeing and publishing policies and the availability of R&D funds for the underlying research are among factors that affect the production of scientific and technical literature.

Implications of Agricultural Research Productivity on Cost of Other Federal Programs

Ag-food productivity and efficiency---in terms of primary production, fabrication and processing, preservation and distribution over time and space---also has a direct impact on the cost of other federal programs. There obviously is a direct relationship between the cost of the food stamp program and other food aid programs and efficiency in the production, preservation and distribution of food. Poor performance in terms of input (especially labor)-output relationships and avoidable food losses all increase costs of food aid programs.

The U.S. Government has adopted the policy of providing an adequate diet for all its citizens regardless of the individual level of affluence attained in the competitive system. Food aid to destitute and near-destitute citizens has taken various forms. The local (county) poorhouse dominated the public food aid that was provided destitute citizens in the early part of the 20th century. The federal government became involved directly in food aid with surplus commodity distribution programs during the 1930s. Programs were implemented subsequently to provide milk and/or full lunches to underprivileged school children. The food stamp program replaced commodity distribution programs as the federal government wound down its commodities purchase programs to bolster prices of farm products. Although food stamps can be exchanged only for food, when used in conjunction with other welfare programs it is in essence another income redistribution program. Nevertheless, the cost of the food aid programs is directly linked to the retail cost of food. The cost is related subsequently to productivity and efficiency in the ag-food sector.

The food stamp program rapidly is becoming a substantial item in the federal budget (Table 5.4). Total cost of the food stamp program was a rather modest $578 million in 1970 but increased each year during the decade except 1977 to a substantial $6.9 billion in 1979 and an unofficial estimate of $9.1 billion in FY 1980. The cost of the food stamp program---given a specified level of nutrition---is directly related to the availability and cost of food. Output increasing and cost reducing technology will constrain the growth in the cost of the food stamp program. However, a quantification of this relationship is not available.

Other food aid programs were estimated at $4.5 billion in FY 1980. Total expenditures for food for the armed forces are not available. However, expenditures by the Defense Personnel Supply Center in FY 80 were estimated at $1.3 billion. Thus, direct government expenditures for food and food aid programs apparently exceeded $15 billion in FY 80. These expenditures could be reduced, in real terms, by increased efficiency in the food production and distribution sectors.

Another area of government activity in which food is a substantial part of the cost is that of maintaining a military capability. Food requirements for the military depend on the size and activities of the armed forces. Due to increasing physical activities, food requirements of the total populace (civilian plus military) increase during wartime or preparation for war. The availability and quality of food also can be a determining factor in the outcome of military confrontations.

There are other government programs and activities where people and food services are involved. The cost of these programs and activities is at least partially related to ag-food productivity and efficiency. Generally, these other programs and activities are of minor importance compared with direct food aid and military operations as it relates to food costs.

Another ramification of the impact of ag-food productivity and efficiency on government costs is rather indirect. Salaries and wages for personnel employed directly, and those embodied in goods and services purchased by government, are the largest components of government costs. All personnel are fueled by food. Thus, salaries and wages and indirect labor costs are related to the costs of food. Food cost is a substantial component of the Consumer Price Index that is used as a leverage to increase salaries and wages, social security payments and retirement payments.

Table 5.4. U.S. Government Food Purchase and Expenditures on Food Aid Programs.

($Millions)

Fiscal Year	Food Stamp Program[a]	Other Food Aid[a]	Armed Forces[b]
1970	577.7	NA	1,031.8
1971	1,576.0	NA	946.4
1972	1,864.3	NA	833.8
1973	2,178.1	NA	830.8
1974	2,845.2	NA	929.7
1975	4,619.4	NA	955.2
1976	5,669.1	NA	1,113.3
1977	5,471.4	NA	1,174.9
1978	5,587.7	NA	1,152.9
1979	6,930.3	4,115.0	1,360.5
1980	9,100.0[c]	4,499.0	1,336.3

[a] Total Federal cost. Source: U.S. Department of Agriculture, Food and Nutrition Service.

[b] Partial military food cost. Data are only Defense Personnel Supply Center (DPSC) expenditures for food.

[c] Unofficial estimate.

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Section VI

IMPLICATIONS AND JUSTIFICATIONS FOR AG-FOOD RESEARCH FUNDING LEVELS AND FUNDING MECHANISMS

[Data are available on state and federal funding of ag-food research and the use of the funds with respect to program area and research problems. Presumably these data will be presented in other parts of the OTA assessment. Thus, this section is devoted to rationale and to funding justification.]

Ag-food research, or more specifically the funding of such research, is justified on the basis of benefits stemming from the research. Past and continued funding is justified to the extent that the benefits exceed the costs (funds appropriated). Costs or the level of funding are relatively easy to document and in considerable detail with respect to source of funds, and the use of funds by performing agency, and by programs and problem areas. However, the benefits stemming from research are more difficult to document and quantify. Nevertheless, there is a growing body of evidence of a relatively high rate of return on investments in ag-food research. Many benefits flowing from research that cannot be readily quantified include: 1) improved quality, safety and variety in foods; 2) release of labor to other sectors in order to provide an array of higher-order goods and services; 3) reduction of drudgery in farming and the increase in leisure time of the entire populace; 4) enhanced capital formation in the ag-food sector and other sectors of the economy; and 5) aesthetic and environmental enhancement.

Public investment rests basically on the presumption that the benefits will exceed the costs. The monetary benefits stem from increased labor, capital and resource efficiency in producing, storing and distributing goods and services. The value of some of these goods and services is determined in the market economy---including food, clothing and shelter. To some extent quality attributes and convenience also have monetary value in the market place. However, there is no market monetary value placed on many government expenditures such as protection against foreign and domestic enemies and crime, free access highways and waterways, regulation of industry and trade, etc.

It is presumed that government investment in education, research and development will enhance economic productivity---especially labor productivity---and contributes to social tranquility. Productivity can be quantified and documented, social tranquility cannot. Neither can the value of environmental quality and numerous aesthetic attributes be quantified and documented. Nevertheless, these things are important to the well-being of the populace and require expenditures by governments.

Decisions concerning the level of taxes and the appropriation of tax revenues are based predominately on legislative judgment. Part of the taxing and appropriation mechanism is simply a transfer of buying power (income) among various segments of the populace---i.e., social security programs, welfare programs, veteran's programs. However, the fact remains that wealth (represented by the production of goods and services) cannot be transferred until it is created. Price inflation basically is due to creating dollars at a rate that exceeds the creation of real wealth.

Research related to the ag-food sector contributes to the creation of national wealth. However, the magnitude of the contribution and the flow of the wealth created have not been quantified with a high degree of accuracy. There are estimates of rates of return on public investment in research, contributions to economic surplus, etc. However, these estimates are subject to reservation due to inadequate data and statistical estimation procedures. To date, our knowledge about the flow of benefits to consumers over time and space is limited.

Rationale and Justification for Maintaining Current Funding Methods or for Changing Levels and Methods of Funding

Funding for ag-food and related research primarily stems from five sources: 1) the federal government; 2) more than 50 state and commonwealth governments; 3) private industry; 4) commodity and trade associations; and 5) private foundations. Although county (local) governments provide funds for extension activities, only limited research funding is provided at the local level. Ag-food research is conducted by several federal agencies (largely within the U.S. Department of Agriculture), all land grant institutions and associated experiment stations, nonland grant public institutions, private institutions, industrial firms and perhaps others. Directly or indirectly consumers (taxpayers) provide the funding and reap the benefits of ag-food research. In that the USA is a net exporter of food, fiber and related products, the USA is also a net exporter of direct benefits stemming from ag-food research.

Although consumers support research and reap the benefits, there are questions of equity due to the interstate and international flow of food, fiber and related commodities. Producers (including farmers) benefit from expanding demand (domestic and foreign) and from reduced costs. Likewise consumers benefit from rising real income (expanding demand) and reduced costs. Distribution of these benefits depends on the elasticities of supply and demand. In the case of ag-food and related commodities, it is generally conceded that most of the benefits flow to consumers given time for widespread adoption of emerging technology.

The USA ag-food sector operates under a policy of free trade among states with competitive forces allocating production among states. The distribution of consuming population among states is related to distribution of primary ag-food production only to a limited degree. Thus, from the equity considerations of the geographic distribution of costs associated with ag-food research and the benefits flowing from this research, exclusive federal funding of ag-food research would be the most equitable. This is the highest level of government with taxing power and funds. However, federal funding relative to individual state funding has decreased as the interstate flow of commodities has increased. This is true especially of research conducted by state agricultural experiment stations. Subsequently, taxpayers in food surplus states are subsidizing consumers in food deficit states and the degree of the subsidization is increasing.

The major justification for support of ag-food research at the individual state level is that of enhancing and/or maintaining the competitive position of the individual state in the national and international markets. Although the market demand for food in total is highly inelastic at the national level, this is not necessarily so at the individual state level. This means that an individual state can increase food production at a relative rate exceeding the decrease in price. At the national level, for food in total and most individual commodities, an increase in production results in a larger relative decrease in price and a reduction in gross revenue at the farm level. Research and innovation contributing to reduced costs always increases economic surplus and in the case of food and related commodities most of the increased economic surplus accrues to consumers.

The equity issue clearly supports the argument for federal funding of ag-food research relative to individual state funding. However, this does not resolve the issue as to whether federal, state or private agencies (or firms) conduct the research. Neither does it resolve the issue of the level of funding in total or for specific programs.

A relatively high rate of return on the current level of public investment in ag-food research supports the argument for an increased level of funding. From a purely economic perspective, additional increments of funding would be applied where the pay-off is greatest---this would continue in an iterative fashion ad infinitum. However, this applies to government funding only where the value of the output is determined in the market.

Nonmarket values would have to be estimated---for example, what is the value or benefits of a clean environment or social tranquility? And what is the trade-off between these goals and marketable goods and services? Resources are scarce always, but the wants of society are infinite. Allocation of resources to accomplish the myriad of goals and objectives for satisfying society's wants occurs largely in the market and in the legislative bodies of National and state governments.

Approaches for Determining the Size of Research Investments for Each Method of Funding

The U.S. Department of Agriculture - land grant colleges and universities system provides the research and education (on and off campus) that undergirds the most productive agriculture and food sector that ever existed. There are few if any reservations with respect to maintaining this system with desirable modifications. The modifications revolve around the issue of making the system more productive and more responsive to societal needs.

Each institution in the system consists of a staff with very specific and specialized skills and knowledge. This expertise is a very valuable national asset that evolved over a long period of time. The nature of the expertise can be modified only gradually over time. Persons possessing specific knowledge and skills must also be replenished over time. With changing emphasis on research programs and problem areas, the flow of persons trained in specific disciplines can be increased or decreased gradually but cannot be changed radically in a short time.

The geographic distribution of persons with specific knowledge and skills also has evolved over a long period of time and can be redistributed only gradually. These features of the system require rather stable and consistent real dollar funding. The quality and quantity of the stock of expertise can be increased gradually over time with increased real funding or decreased gradually with reduced funding.

Funding levels necessary to maintain faculties at prescribed levels or rates of change, with specified levels of support, equipment and buildings can be determined readily. Issues concerning change in real funding levels then revolve around the desirability of increases or decreases in the total faculty and/or its disciplinary components. Virtually all faculty members possess specific disciplinary skills and knowledge, but many research programs and problem areas require multidisciplinary input. This can be accomplished best through voluntary cooperation with administrative guidance and support.

There are two basic sources of funds considered here---the federal government and individual state governments. There also are two basic methods of funding---continuous funding and sporadic funding.

Continuous funding is defined here as continuous stable real dollar funding---that is, it is not continuous and stable until it is adjusted for inflation. Funding also may be continuous and increasing over time in accordance with population, school age population, economic development, economic and social complexity, etc. The important consideration for faculty maintenance and enhancement is consistent and reliable funding under rather specific ground rules for each institution.

Sporadic funding takes different forms and is used for different purposes but its essential feature is the unreliability from the perspective of the individual institution. Sporadic funding cannot be effectively used by the institution to maintain quasi-permanent faculty and programs. Therefore, the sporadic funding methods are less desirable and probably less effective than continuous funding.

Sporadic funding can be used effectively to initiate new programs (seed money), provide specialized equipment or buildings that would not otherwise be available, provide additional support staff, etc. Sporadic funding can be used also to gain a greater degree of control over the use of funds by the funding source---i.e. promote pet or popular research programs.

One type of sporadic funding that is controversial in terms of effective use of professional expertise is that of competitive grants. A great deal of professional time is embodied in preparing competitive grant proposals that are not funded, and a great deal of additional professional time is expended in reviewing the myriad of proposals with only a few funded. Also, there are reservations with respect to the knowledge that evolves under competitive grants relative to that which would have otherwise evolved from the same source without the grant. Moreover, a high degree of competition among scientists for recognition and pecuniary rewards already exists.

The argument is rather clear that continuous and reliable funding is more effective than sporadic funding. However, considerable attention should be devoted to such issues as: 1) What rate of change (increase or decrease) should be incorporated in the real dollar aggregate level of funding over time for the total ag-food research program?; 2) What programs or problem areas should be expanded or contracted proportionately to the total?; 3) What is the most equitable source of funding given the distribution of benefits?; 4) What is the most effective method of funding?; 5) What is the most effective distribution of funds in total and for specific programs?; and 6) What are the important evolving issues and problem areas? These issues are being addressed in other papers commissioned for the U.S. Congress, OTA assessment of ag-food research.

Commissioned Paper IV

THE ROLE OF THE FEDERAL GOVERNMENT, STATE AGRICULTURAL EXPERIMENT STATIONS, AND THE PRIVATE SECTOR IN RESEARCH

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Office of Technology Assessment
U.S. Food and Agricultural Research
Work Group II

Paper #4

AUGUST 1981

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SUMMARY AND RECOMMENDATONS

A common observation by agriculturists from abroad who visit the United States to study the national agricultural research system is that the system--composed of a strong national research authority, a strong and widely dispersed state authority and responsibility, and a growing involvement in recent decades of the private sector--is unworkable. Yet, as a developing nation from early colonial times through essentially the World War II period, and as one of the most rapidly advancing developed nations from that time to the present, this cooperative system has been a major force in achieving the most productive and efficient agricultural sector the world has known.

The co-authors undertook the preparation of this paper with the full realization that many of the basic issues to be assessed are controversial and it is difficult to subdue personal biases based on the involvement and experiences various people have had with the national agricultural research system. The adage "where you stand on an issue depends on where you sit" is fully applicable to an assessment of the nature and scope of the subject of this paper.

The Office of Technology Assessment's evaluation of the U.S. Agricultural system raises several questions. Is the system well regarded by interested observers? Is it adequately funded in the views of participating scientists? Is it adequately organized and managed? What are the roles of the federal government, state agricultural experiment stations, and the private sector; and are these roles being adequately played? In substance, is the system healthy or not, and if it ails, what are the limitations and constraints?

This paper deals with the respective roles of participants in the system, and how they may have changed over time, and with attempts to diagnose limitations and constraints that may impact on how well those roles have been and are being played. In this regard, the paper, and perhaps some others in the OTA study may appear harsh in describing defects. However remedial measures cannot be prescribed until the needs of the patient are identified.

Much of what is presented in this paper reflects the experience and judgments of the co-authors. The study was not approached as a literature review but rather depicts the cumulative experience of the three co-authors which spans many years and a variety of positions and perspectives in the cooperative research system. Points are made with conviction, realizing that these may not always be acceptable answers or necessarily the right ones. However, those in OTA responsible for preparing the eventual reports must have substantive materials to utilize, or to depart from.

The paper covers the following five subject areas:

1. Evolution of Research in the U.S. to World War II
2. Changes in the 1945-1960 Period
3. The Era of Rapid Change, 1960-1980
4. Current Status
5. Realignments in the National Research System

Evolution of Research in the U.S. to World War II

Much of the information about evolution of agricultural development in the American colonies is extracted from the book by A. C. True on the history of agricultural experimentation and research in the United States, covering the period 1607-1925. Special attention was given to those items in this early period that reflected the attitudes of national leaders and the Congress toward public support for agricultural development. Also, particular attention was given to those actions by the Congress and various national leaders that served to identify the anticipated role of the federal government, the emerging state educational and research institutions, and the relationships between them. From this early history it would appear that the Congress, at least the House Committee on

Agriculture, envisioned that the Department would provide the national leadership for agricultural development, including the administration of research funds provided under the Hatch Act and other legislation. On the other hand, it seems evident that there was a full intent to have substantial autonomy on the part of the State Agricultural Experiment Stations (SAES), individually and collectively, as specified in the Hatch Act of 1887, the Research and Marketing Act of 1946, and other legislation.

The national and regional research and development programs, such as the work in the Great Plains area at the beginning of the century, seems relevant because of the mutual awareness of the USDA and the states that there should be joint support and concern about research and development in the region. This cooperative endeavor furnished the base for the subsequent coordinated national commodity improvement programs--a sophisticated partnership in which federal and state researchers maintained a high level of mutual respect, and the federal "investigations leaders" played a significant but not domineering role. The quality of this federal/state cooperation covered a significant span of years, as exemplified by the recognition by Dr. H. K. Hayes of the Minnesota Agricultural Experiment Station of the importance of the coordinated corn improvement program, established in 1926 with Dr. F. D. Richey of the USDA as the coordinating leader, through the current assessment by Dr. R. W. Howell, of the Illinois Agricultural Experiment Station, with respect to the cooperative soybean research extending into the 1970's.

Perhaps the most significant feature of the relationship between the USDA and the SAES through the World War II period was that while there was a "never ending search for adjustments between the stations and the department as to the division of responsibility for research in the states" there evolved a philosophy of cooperation that continually kept in mind the importance of serving the public that required the national research system--and supported it.

Changes in the 1945-1960 Period

A major factor in this era was the reduced emphasis on production research, reflecting the "burdensome" surpluses of agricultural commodities following World War II and--except for a brief interlude in 1951-52--following the Korean War. This caused conflicts within the national research system and especially between national policy makers, who wanted reduced production research, and industry leaders who clearly saw needs for problem solving or mission-oriented research. It also perhaps caused some reduction in cooperative efforts between the USDA and SAES.

The realignments in cooperative relationships, the adjustments in soil and water research and in other subject areas, and the geographic shifts in U.S. agriculture were made in the continuing atmosphere of mutual concern and respect that marked the relationships of the USDA and the SAES during the previous decades.

The Research and Marketing Act of 1946 furnished a greater degree of freedom for cooperation among the states. But it also served to lessen the bond between the USDA and the SAES through establishment of "independent" regional activities by the states under the regional research fund. This independence persisted particularly through the late 1940's and 1950's, but has since matured to a more cooperative model, especially in the late 1960's and during the 1970's. This should not be judged as being either good or bad--but the relationships did change and the current model of cooperative regional efforts are somewhat different than those that prevailed through World War II.

Collaboration of the USDA and SAES with the private industries concerned with agriculture was strengthened during this period when the mechanization and the chemicalization of agriculture became more significant. The private industries related to agriculture became more active in research and made many significant contributions to improving efficiency and productivity of U.S. Agriculture. Again, the cooperative spirit that was reflected in the development of the national weed research program, as reviewed in the paper, reflects the existence of a mutually acceptable working relationship, embracing both the public and private sectors.

The reorganization of USDA research in 1953 is given prominence in the report because it marked a divergence from the continuous evolutionary changes in organization to a very abrupt and substantial change that had reverberations over future decades. It is recognized, in the retrospective assessment of the 1953 reorganization, that working relations in the field involving USDA and SAES scientists in programs such as those concerned with national commodity improvement, persisted through the 1950's, 1960's, and into the 1970's. The major impacts or disruptions apparently were at the national research management and the national and regional administrative services levels.

In the 1945-1960 time span, the linkages between the USDA and the SAES were loosened, but not necessarily strained. Private industries played a more prominent role in the research and services to an agricultural sector that was less hard-pressed for output and was somewhat less demanding on public sector research for production-related inputs. However, the need for protective research, to meet the continuing new hazards of pests and diseases, together with research to improve efficiencies in production, processing, and marketing, persisted.

The Era of Rapid Change, 1960-1980

The past two decades have been the period of significant change in the national agricultural research system. It is most difficult to identify, assess, or assign any type of priority to the importance of the relevant factors. It will be essential to weigh not only the views expressed in this paper, but also the reactions of many others with different perspectives and different value judgments of the component factors.

The availability of substantial amounts of project grant funds from various federal agencies following the "post-Sputnik" era beginning in the late 1950's changed the direction of interests of many research workers in the SAES. While project grant support was received for studies related to agriculture, they were "basic" and not concerned with problem solving or with constraints to agriculture. With external funding, some scientists became less responsive to the leadership of the SAES, with a deteriorating effect on the discipline or line authority of those organizations.

With the lack of grant funds for "basic" agricultural research from various federal agencies, there was a strong push for USDA to provide such support. There are differences of opinion with respect to the significance of this factor, but it would be difficult to deny that it has affected the nature and amount of support for the USDA and the SAES in the past decade.

The reviews of agricultural research, by the President's Science Advisory Committee in 1962, and by the National Academy of Sciences Committee in 1969-72, had an impact on USDA/SAES relationships, in part because each of these reviews was conducted by committees composed largely of university scientists and administrators, with little or no representation from the USDA. The recommendations of the PSAC committee of 1962 were assessed and acted upon internally, involving primarily USDA and SAES personnel in the Department of Agriculture, with significant changes made, but with little public controversy. On the other hand, the NAS review of 1972 produced substantial publicity, primarily in Science, stemming largely from reports of the separate panels rather than from the committee report itself. The Science articles were highly derogatory of the USDA research output and leadership, and did not enhance the relationships between the USDA and SAES.

The 1972 reorganization of the USDA is perhaps the most persistently controversial issue and factor for assessment in the current study. It has been widely presumed that this reorganization stemmed from the 1969-1972 study of the NAS committee. However, this is not the case and the architectural responsibility for the 1972 reorganization of the USDA rests with a limited number of officials in the Department.

The direction of agricultural research has been realigned to meet growing concerns with respect to environmental pollution, human health hazards from various agricultural chemicals, and diverse social and economic concerns of consumers. These are of growing significance and require changes in emphasis or priorities in the national research system. However, they are subject to the same type of cooperative research and basic philosophies that characterized the working relationships between the USDA, SAES, and the private sector from the beginning.

Current Status

Special emphasis in assessing the current status of the national agricultural research system is focused on the present organizational structure of the USDA, particularly with respect to its effectiveness in meeting national and regional responsibilities for agricultural research. The 1972 reorganization dispersed much of the USDA line authority and responsibility for research to "regions" of the U.S. coinciding with the SAES regions, and to various areas composed of two or more states, and of the five regional laboratories, much as was the case in the realignments of Soil and Water Research in 1953 and 1961. The retention of essentially staff functionaries in the headquarters, with reduced authority and detached from the working programs of field and laboratory research, poses serious questions about the capacity of the USDA either to identify national and regional research needs or to respond to them.

Attention is directed also to the mechanisms for determining research needs and priorities, in developing budget requests for research of the USDA, the federal funds for support of the SAES, and the magnitude and nature of project grant funds. There is serious disagreement among the authors as to the current status of program planning, budgeting, and research operation and management. The senior and private sector authors perceive a serious breakdown in the system for program planning, budget development, and research operation and management that must be mutually joined if the cooperative efforts of USDA, SAES, and the private sector are to be re-established and maintained. The university employed author contends that the system of regional and national cooperative planning evolving from the 1966 national study, the establishment of the Agricultural Research Policy Advisory Committee, and later, the Joint Council on Food and Agricultural Sciences; and the planning and budgeting processes envolving therefrom in fact have substantially re-established and strengthened the cooperative program planning, budget development, and research operation and management of the cooperative efforts. The weaknesses he perceives are that the budget develop[illegible] process breaks down when it becomes separated from the planning process and that the planning process may be too dominated by management.

There has clearly been evolution in the roles played by the USDA, SAES, and the private sector, the three major partners in agricultural research in this nation over the past 100 years or more. There have been significant shifts in the level of participation, particularly in the agricultural experiment stations and in the private sector relative to the total efforts in the system, with those two emerging--particularly since World War II--as much larger contributors to the total. And, of course, with the passage of the Research and Marketing Act of 1946, a distinctive change in role and responsibility in regional research emerged for the agricultural experiment stations.

However, it is the authors' perception that the principal and basic role of the three partners has not really changed over that span of time. All legislation relating to the department's program dating from the Organic Act of 1862 through the Title XIV of the Food and Agricultural Act of 1977 continue to stress the national, regional and, more recently, the international leadership role for the department. Similarly, the principal and basic role of the state agricultural experiment stations has always focused on "differences among the states" with the added dimension of the regional research fund program in 1946 which suggests some sharing of responsibility between the department and the stations. And Title XII of the 1975 amendments to the Foreign Assistance Act laid a heavy responsibility on the Land-Grant Universities to increase their contributions internationally. Private industry has always been looked to for research and developmental activities relating to agricultural business and industry with the principal thrust, of necessity, being on those innovations that could be developed to a profit making status within our free enterprise system.

The foregoing constitute the basic guidelines under which the system was originated and has evolved over the years. Within those basic tenets, the system has been studied and restudied, and has struggled mightily within itself to find mechanisms though which those roles might best be played, sometimes generating significant stress in the process. A major part of this paper deals with interpretations drawn from a wide variety of events with the objective to attempt to identify constructive recommendations that might enhance the ability of the actors to fulfill those roles within the context of the whole system.

Realignments in the National Research System

The U.S. national agricultural research system has been functioning for more than a century--following the establishment of the U.S. Department of Agriculture and the provision for the Land Grant colleges in 1862. A system that is vital in meeting critical needs of a developing country, of a maturing nation, and of a democratic society confronted with divergent and changing requirements must adapt to the public it serves and which supports it.

The national agricultural research system has changed--through evolutionary processes for many years, and through more abrupt changes in the past thirty years. Some of these changes have enabled the system to serve its public more effectively. Some perhaps have not. There is evidence that the system may not be functioning as well as it needs to in 1981, at a time when leadership for agricultural science and technology--nationally and internationally--has never been greater.

There are surely many minor modifications that might be made to improve the U.S. Agricultural Research system. We will deal here only with several major matters that are essential in maintaining strength of the national system and in facilitating more effective interaction and mutual support of the components of the system, the U.S. Department of Agriculture, the State Agricultural Experiment Stations, and the private industries related to agriculture.

The following matters need attention:

1. Maintain a strong role for research and education in policy decisions affecting U.S. agriculture.
2. Strengthen the role and authority of scientific leadership in the USDA to provide participatory, integrative leadership for international, national, and regional research programs.
3. Revise the administration of SEA-AR to improve efficiency, clarify responsibility, and shorten lines of communications.
4. Strengthen the Beltsville Agricultural Research Center and other national and regional research stations and laboratories.
5. Continue to bring cohesion to national and regional research programs by locating facilities and staff of USDA to the maximum extent possible at cooperating state agricultural experiment stations.
6. Strengthen the linkage between program planning and budgeting.
7. Eliminate the negative impacts of zero-based budgeting on the continuity and stability of research programs.
8. Reassess project grant funding through the U.S. Department of Agriculture.
9. Strengthen cooperation of USDA and SAES with the private sector.

The substantive issues with respect to the foregoing items are discussed in detail in the paper and will be reviewed only briefly in this summary.

1. Maintain a Strong Role for Research and Education in Policy Decisions Affecting U.S. Agriculture

The scale and complexity of the research and education establishment in the U.S. Department of Agriculture and the scope and complexity of matters dealt with by the department have increased dramatically since World War II. This has resulted in substantially less direct contact of and access by research and education managers in the department with top departmental policy makers. In the extreme, there have been times when representations in policy matters were expressed only by a part-time voice.

Until the early 1950's research leaders of the USDA, including the Chiefs of Bureaus and the Head of the Office of Experiment Stations had direct contact with the Secretary of Agriculture through fortnightly staff meetings called by the Secretary. Secretary Benson terminated these meetings, but had some continuing contact with the Agricultural Research Administrator. However, the lines of communication with the Research Administrator (and occasionally some Bureau Chiefs) were primarily through the Assistant Secretary for Research and Extension. Following the reorganization of 1953 the Directors of Research and others at this level had less frequent and primarily informal contacts with the Assistant Secretary.

In 1963, when Frank Welch, Assistant Secretary for Research and Extension, left his position this Assistant Secretary post was transferred to the person responsible for international programs of the USDA. A. H. Moseman served briefly (from March through June of 1963) as "Science Advisor" to the Secretary. The position was realigned to "Director of Research and Education" when Nyle C. Brady took over the duties for the 18 month period beginning in late 1963.

The PSAC Agricultural Panel, in its report of January 1962, recommended that there should be appointed an Assistant Secretary for Science and Technology in the USDA, to devote full attention to the Department's activities in both domestic and foreign science and technology. This position has not been established and so the linkages of the heads of the agricultural research service and the cooperative state research service remained downgraded, serving under a Director of Science and Education until the responsibility was assumed by the Assistant Secretary for Conservation, Research and Education in the Nixon-Ford administration. It remained so until the middle of the Carter term when the Director of the Science and Education Administration reassumed the policy role as Director of Science and Education.

In view of the importance of a strong and responsive agricultural research program, both nationally and internationally, it would seem essential to provide for a more direct relationship to the Office of the Secretary. This should preferably be done through establishment of an Assistant Secretary for Science and Education, providing the stature and position of research in policy matters that it had until 1963.

2. Strengthen the Role and Authority of Scientific Leadership in the USDA to Provide Participatory, Integrative Leadership for International, National and Regional Research Programs.

There is substantial evidence that the present national leadership and liaison role provided by the national program staff of AR lacks necessary strength in providing leadership for research at the national and regional levels, in relating to cooperative regional and national programs involving SAES scientists, and in relating to the regional and area positions of AR.

The relationships between the USDA and SAES which evolved from the beginning of the present century--through the cooperative work on dry land agriculture in the Great Plains, through the various commodity improvement programs, and in other joint enterprises--proved to be mutually satisfactory when these national or regional programs were coordinated by "investigations leaders" who were USDA scientists actively involved in and knowledgeable about the cooperative research throughout the respective program area.

As stated by Paarlberg (1980) some form of leadership for regional and national programs is essential and a loose voluntary cooperative type of guidance is desirable. He points out that the Department of Agriculture is central, it is directly involved in acquisition and distribution of federal funds, and so it comes closer to perceiving the broad public interest than does any other organization in the national research system.

One of the responsibilities of the research system in the USDA is to provide leadership in national and regional research programs. This function appears to have been neglected because of the in-creased emphasis placed upon accountability for funding, counting science man years, and other strictly administrative details.

The National Program Staff is the one area in the present organiza-tion where this function could be performed. This staff should be made up of leaders or individuals who have the potential to become leaders in the various areas they control. One of the principles of good management is that authority must accompany responsibility. Therefore, this group should be assigned both the responsibility and the authority to make final decisions on research programs in their areas of expertise.

It would continue to be the function of the regional deputy administrators to see that these programs are properly carried out in their respective regions.

3. Revise the Administration of SEA-AR to Improve Efficiency, Clarify Responsibility, and Shorten Lines of Communications.

There is little convincing evidence of the need for the area director positions of AR either in serving research leadership or administrative functions. There is perceived to be some utility in these positions in facilitating communicatons between SAES administrators, and in providing AR leadership on problems of local, state, and area concern. However, given that these positions are occupied by highly trained, well-paid scientists it would seem that they could contribute significantly more to the national research system if they were reassigned to working positions at field stations or laboratories, or to regional or national investigation leadership assignments.

4. Strengthen the Beltsville Agricultural Research Center and Other National and Regional Research Stations and Laboratories

The PSAC panel of 1962 recognized the importance of having a strong and reputable national agricultural research center, commensurate with the stature of U.S. agricultural research in international agriculture. The continued timidity in recent years in supporting research facilities or staffing at the Beltsville Research Center has rendered the center not only less effective in furnishing research leadership and scientific inputs, but has reduced the efficiency of conducting research at this location because of inadequate technical and support staff for efficient use of the present facilities.

The location of new laboratories and the allocation of more resources to Beltsville, as contrasted with alternative locations, requires a sense of conviction on the part of the leadership of SEA as well as a commitment to research by the Secretary of Agriculture (as pointed out by Pound, 1980). The USDA library was erected at Beltsville in the mid-1960's when the Secretary of Agriculture took the position that "the location of USDA research facilities would not be determined by the White House staff, or others, but by the Department." The justification for strengthening other national and regional research stations and laboratories is that these facilities exist, they were designed to serve national and regional requirements, and they should be put to good use in meeting the needs of both the USDA and the SAES in improving the nation's agriculture.

5. Continue to Bring Cohesion to National and Regional Research Programs by Locating Facilities and Staff of the USDA to the Maximum Extent Possible at Cooperating State Agricultural Experiment Stations

A major factor in the close cooperation of the USDA and the SAES has been the association of research staff working either in federal laboratories or in state owned facilities at the cooperating SAES. This has been basic in maintaining strong cooperative relations and in sustaining mutual respect of the cooperating partners, and should be given high priority in the future strengthening of the national agricultural system.

6. Strengthen the Linkage Between Program Planning and Budgeting

Dissatisfaction with the present procedures for program planning and budgeting have been expressed by Pound (1980), Castle (1980), the North Central Agricultural Experiment Station Directors Association (1980), and others. Castle

(1980) states, "One finds little appreciation or understanding in the legislatures of the vast, wasteful, and intellectually sterile planning and coordination process which exists. A much simpler system undoubtedly would serve political needs just as well as the one in existence. Just so the record is clear, permit me to say that the regional planning that existed prior to the establishment of the Joint Council was not much, if any, better. Neither are these remarks intended as an anti-USDA tirade. The realignments stemming from the work of the Joint Council have simply resulted in the current conflicts of which many are so weary. But the fault is not really with the USDA or the Joint Council. As near as I can tell the fuss is over who is going to control an irrelevant, cumbersome, wasteful, planning and coordination system."

Many others, including the university and private sector authors of this paper, take strong exception to those perceptions and suggest that the weaknesses are not in the organizational mode or the process of planning. Rather, they acknowledge some weaknesses in that the mode and process are overly dominated by management, thus perhaps failing to contain sufficient scientific content. Of perhaps greater significance, when the budget goes behind the curtain, the budgeting process loses contact with the planning process.

These are long-standing, persistent issues, and require improved communications as well as improved procedures. Failure to coordinate or integrate program plans and budgets, resulting in a lack of distinction as to the needs and purposes of USDA research funds and SAES grant funds, is detrimental to both partners in the national system.

7. Eliminate the Negative Aspects of Zero-based Budgeting on the Continuity and Stability of Research Programs

It is generally recognized that essential and productive agricultural research must have continuity and stability. Many aspects of such research, concerned with new or recurring disease and pest hazards, must be essentially continuous. Zero-based budgeting, as practiced in recent years, has created an instability that is not only detrimental to current research--requiring excessive time and attention from research leaders to justify continuation of research--but also is a definite deterrent to attraction of able young scientists to research positions in AR. This matter requires prompt and serious attention.

8. Reassess Project Grant Funding through the U.S. Department of Agriculture

Procedures for funding competitive grants have been controversial since provision of such grants through the U.S. Department of Agriculture was considered beginning in the early 1960's. It was proposed at that time that the grant funds be handled in association with ARS budget requests, to permit identification of the funds with specific subject areas. The alternative, to have the grant funds requested through the CSRS, was the procedure decided upon.

Recent concerns about provision of competitive grant funds through reduction of formula funds reflects broader uncertainties with respect to definition of research program plans and requirements for (1) in-house AR research, (2) formula grant funds, and (3) competitive funds. This is an integral component of the broader issue of program planning and budgeting, to be addressed jointly by the USDA and SAES.

9. Strengthen Cooperation of the USDA and SAES with the Private Sector

The report reviews various facets of research that are undertaken, some increasingly so, by private industries concerned with agriculture. On the other hand, there are numerous activities that will not or cannot be undertaken by the private sector because of the nature of the problems or the magnitude of research investments in relation to potential returns.

With the increasing concerns about air and water pollution, various other environmental and health hazards, and numerous energy-related issues involving agriculture, it is essential that the public should have the most reliable information possible from in-depth research on these issues. Strong interaction and cooperation between public and private organizations in conducting research on the foregoing critical issues would seem to be in the best public interest.

It is essential that the U.S. continue to have sustained inputs of technology from the agribusiness sector. The frank and open working relationships between the USDA, SAES, and private industry that evolved to the early 1960's were sidetracked somewhat by the reverberations of Silent Spring in 1962, and the subsequent criticisms of the agribusiness and public sectors. These criticisms were not only disruptive, but in many cases were superficial. They should be put behind us and the public-private cooperation in the U.S. national agricultural research system should be restored and strengthened.

The director of SEA and Administrators of AR, CR and many of the individual scientists have attempted to maintain good working relationships with industry organizations in order to maintain a better knowledge of what research is being accomplished in the private industry. This has been done in an effort to substitute for the industry advisory committees which have been abolished. These individual attempts are real and sincere. They should be encouraged but better methods should be developed which would be more efficient and less time consuming for the individuals involved but still accomplish the purpose of some information on what industry is doing in research. This is essential to avoid unnecessary research programs and duplication of effort. Industry should also be encouraged to present research problems which they are not either capable of or possibly not inclined to investigate.

Mechanisms should be developed for improved communications, interactions, and development of the mutual respect and confidence that is essential if the public is to benefit from the interacting and synergistic relationships between the USDA, SAES, and the private sector. The restoration of the USDA, SAES, and private sector relationships is less a matter of organizational form and more a matter of operational philosophy, with major emphasis on the identification of the primary role and responsibility of each of the institutional partners.

THE ROLE OF THE FEDERAL GOVERNMENT, STATE AGRICULTURAL EXPERIMENT STATIONS, AND THE PRIVATE SECTOR IN RESEARCH*

I. EVOLUTION OF RESEARCH IN THE U.S. TO WORLD WAR II

A. USDA

1. Development of Agriculture in the American Colonies

American agriculture evolved from those plants such as maize, beans, pumpkins, and tobacco--grown by the native Americans--and the cereals, fruits, and vegetables introduced by European settlers. As stated by True, 1937, "the first permanent English colonists in North America, at Jamestown, Virginia, in 1607, and Plymouth, Massachusetts, in 1620, profited greatly from the primitive agriculture of the native Indians, but soon set about improving it." In addition to the native crops, and the plants and husbandry practices introduced by the immigrants, special explorations were made to Central and South America, as well as to the West Indies and to the Old World to collect new species and varieties of crop plants.

Support from the Government for agricultural development of the colonies was appreciated at an early date. In 1622 James I of England encouraged the breeding of silkworms. In 1642 the general court of Massachusetts offered premiums to encourage the raising of sheep. Land grants were made in Virginia and Georgia, on the condition that mulberry trees would be grown for the production of silk.

William Penn, the leader of the English settlement in Pennsylvania in 1681, imported well-bred horses, experimented with the growing of forage crops, and encouraged his fellow settlers to continuously improve their agriculture. The secretary to William Penn, James Logan, who came to the colonies in 1699, is recognized as being "the first scientific agriculturalist in this country." He first recorded how the grain of maize resulted from the union of the pollen of the tassel with the silk of the ear. The farmers of Connecticut, after noting that the "blast" of wheat was associated with the proximity of barberry bushes, secured a law in 1726 for the eradication of such bushes.

George Washington undertook the study of agricultural problems systematically in about 1760 at Mount Vernon and nearby plantations. Thomas Jefferson, who was interested in a wide range of physical and biological phenomena, also conducted experiments in agriculture and introduced many new crops and farming practices.

Following the Revolution, agricultural improvement was accelerated through the formation of societies for promoting and improving agriculture. Such societies were organized in South Carolina in 1784, in Philadelphia in 1785, in New York in 1791, in Massachusetts in 1792, and in Connecticut in 1794.

Leaders of the societies, and the societies themselves, were closely associated with the educational institutions of that period. Of some special interest is David Hosack, who studied at Columbia College, graduated from Princeton in 1789, and gained a degree in Medicine from the College of Philadelphia in 1791. In 1794 he brought back from England and Scotland an extensive collection of minerals and a duplicate collection of plants from the herbarium of Linnaeus. He served as a professor of botany in Columbia College from 1795 and, in 1801, purchased twenty acres of land in New York City, between 47th and 51st Streets and 5th and 6th Avenues. This tract, the Elgin Botanic Garden, served as the experimental field for introduction of approximately 1500 species of plants collected from Europe, America, and the East and West Indies. By an act of the state legislature this garden was transferred to the state of New York in 1810 and in 1814 was granted to Columbia College. No funds were provided for its maintenance and the Botanic Garden was subsequently abandoned. More than a century later, this site served for the development of Rockefeller Center--a land grant to Columbia College (now a university) that achieved a substantial increase in value.

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*Work Group II, Paper #4

The Massachusetts Society for Promoting Agriculture, in 1801, subscribed $500 for the establishment of a professorship of natural history at Harvard College. The Society proceeded to obtain subscriptions for the permanent endowment of the chair, followed by a subsequent grant of a half township for the same purpose.

There are numerous other examples of concerted efforts in experimental agriculture to ensure the development of the colonies and the emerging states through the early 1800's. These efforts were a combination of the ingenuity and interest of individuals with an appreciation for systematic investigations and observations. Government land grants were used as one means of supporting agricultural improvement, and there was a close association of agricultural investigations with the educational institutions of that early period.

2. Establishment of the Department of Agriculture in 1862

The first initiative for support for agriculture by the National Government was taken by George Washington who, after consultation with Alexander Hamilton and John Jay, recommended in his last message to the Congress on December 7, 1796, that there should be established a National Board of Agriculture. This was to be designed after the British Board of Agriculture, established in 1793 (True, 1937). It is of interest to note that among those who would not support Washington's proposal for a federal agriculture agency was Thomas Jefferson, who stated "I think Congress cannot find in all the enumerated powers any one which authorizes the act (the establishment of a federal agricultural agency), much less the giving of public money to that use." This view of Jefferson, expressed in 1801, prevailed until 1817 when a petition in the House of Representatives recommending the establishment of a National Board of Agriculture was not given favorable action. This decision rested in part on the awareness that President Madison was opposed to the measure because of constitutional limitations as well as objecting to extending functions and expenditures of the federal government.

A committee on agriculture was established in the House of Representatives in 1820, and in the Senate in 1825. These committees had limited authority and responsibility. Much of the support for agricultural development, a strong emphasis on the introduction of plants and animals from abroad, was furnished through the Secretary of the Treasury. The continuing constraint on the use of federal funds for such purposes is reflected in the circular prepared March 26, 1819, by the Secretary of the Treasury to all consuls, requesting them to procure useful seeds, plants, and inventions, and stating that "no expense can be authorized--but it is possible that the attention of the national legislature may be attracted to the subject, and that some provisions may be made, especially in relation to useful inventions."

The reference to inventions has relevance. The first law providing for patents in the new government was enacted in April 1790 and records of patents were deposited in the State Department. On May 12, 1835, when Henry L. Ellsworth of Connecticut was appointed Superintendent of Patents by President Jackson, he recommended that a separate bureau be created to handle the rapidly increasing business relating to patents. On July 4, 1836, Congress passed an act creating the Patent Office as a branch of the State Department and Mr. Ellsworth was appointed Commissioner of Patents on July 6, 1836. He had travelled extensively in the prairie states prior to 1835 and recognized their agricultural possibilities. He purchased substantial tracts of public land in the region from Michigan to Iowa and, following his appointment as Superintendent of Patents, he established a headquarters for his land operation at Lafayette, Indiana. His land holdings in Benton County, Indiana, totaled to about 65,000 acres at one time.

Commissioner Ellsworth was aware that many of the seeds and plants brought into the country by consuls, naval officers, and private citizens travelling abroad were lost because there was no agency for their preservation and distribution. He therefore suggested, in his report for 1837, that there should be a public depository for such items, which could be dispensed to every part of the Union. The Committee on Agriculture of the House of Representatives reported favorably on a bill to provide an appropriation of $5,000 to create such an agricultural depository in the Patent Office, to be staffed by a clerk designated as an agriculturalist and two laborers. This bill was not passed by the Congress and there was considerable criticism of Commissioner Ellsworth for aiding agriculture without authority from the Congress.

In 1841, the Agricultural Society of the United States was organized at a meeting of friends of agriculture from different regions of the country. Among its endeavors, the society planned to obtain funds for the establishment of an agricultural school and experimental farm in the District of Columbia. The society attempted to obtain a portion of the Smithson Fund for this purpose, but this was unsuccessful and the fund was subsequently used to establish the Smithsonian Institution. The society did not receive substantial support and the organization was terminated after the second meeting, held in Washington in May 1842.

The Patent Office was transferred to the Department of the Interior following passage of the act of March 3, 1849, creating that Department. The 1851 report of the Patent Office contained articles proposing (a) the establishment of agricultural schools and experiment farms in every state and a national agricultural college for education and research, (b) agricultural schools whose teachers also would be investigators, and (c) a plan for an industrial university. The Commissioner of Patents, Thomas Eubank, recommended in the report of 1851 the establishment of an Agricultural Bureau, pointing out that Presidents Taylor and Fillmore had followed the example of Washington in calling Congress's attention to this subject, but all that had been done toward carrying out these views was the employment of a temporary clerk in the Patent Office, whose salary together with the cost of purchasing and distributing seeds were borne by the Patent Fund. There was continuing objection to such an Agricultural Bureau on constitutional grounds as well as through fear that it would serve political purposes.

On January 3, 1859, Commissioner of Patents Joseph Holt invited citizens interested in agriculture from most of the states and territories to meet in Washington, where they organized an "Advisory Board of Agriculture of the Patent Office." This action was criticized by the Congress and led to the resignation of Commissioner Holt as well as a decrease in the Congressional appropriation for agricultural work of the Patent Office in 1859.

The Patent Office report on agriculture for 1860 was prepared under the direction of Thomas G. Clemson, as Superintendent of Agricultural Affairs of the United States. He was a trained scientist in chemistry, geology, and minerology, and had managed farms in South Carolina and Maryland. He was interested in the application of science to agriculture, and promoted the establishment of the Maryland Agricultural College.

The decade of the 1850's was a period of special ferment with respect to agitation for establishing a Department of Agriculture. President Fillmore, in his messages to Congress in 1850, 1851, and 1852 strongly urged the Congress to establish an Agricultural Bureau. The Maryland State Agricultural Society, on February 4, 1852, adopted a resolution favoring the establishment of a Department of Agriculture with a Cabinet officer at its head. This was followed by a meeting in Washington on June 14, 1852, from the initiative of the Massachusetts Board of Agriculture, and with broad representation from the states and territories, to form the United States Agricultural Society. The society brought out a report calling for the establishment of a Department or Bureau of Agriculture by the Congress. This proposal met with strong opposition, led by Senator Stephen A. Douglas of Illinois. However, at the first annual meeting of the society, the resolution stating that "Congress be memorialized to establish a Department of the Government, to be called the Department of Agriculture" with a Cabinet officer at its head, was adopted unanimously. This resolution prevailed through subsequent meetings of the society but it is noted (True, 1937) that "the introduction in 1857 of Congressman Morrill's bill for a land grant to the states for industrial colleges and the widespread interest in this measure in Congress and in the states interfered with the work of the society's committee." In 1859 the society recognized that it had made no progress in obtaining favorable action by the Congress in establishing a Cabinet-level Agricultural Department and, aware that "agitation of the subject might endanger the success of the Morrill Land Bill," the society then reaffirmed its recommendation for aid by the Congress to schools and colleges in the States "dedicated to practical instruction in the principles and processes of agriculture and the mechanical arts."

The advent of the Civil War reduced the activities and influence of the society. During 1860-1861 there was a substantial divergence of opinion whether the responsibilities for agriculture should be vested in a Bureau of Agriculture within the Department of the Interior, in a Department of Agriculture headed by a Secretary at Cabinet Level, or through some other means. A bill (HR 269) reported by its Committee on Agriculture to the House of Representatives on February 11, 1862, was a compromise measure creating a separate department headed by a commissioner to be appointed by the President. This bill, with Senate amendments, was signed by President Lincoln on May 15, 1862. This "Organic Act" directed the Department of Agriculture "to acquire useful information on subjects connected with agriculture in the most general and comprehensive sense of that word."

It is of interest to note that financial support for the development of agriculture--in which more than 75% of the people were engaged--was essentially non-existent until 1839 when the Congress appropriated $1,000 for agricultural work. No funds were made available during 1840, 1841, or 1843, after which allocations were resumed and increased to $5,000 in 1850 and $10,000 in 1854, out of the Patent Office appropriations. In 1855 the expenditures totaled about $40,000 and from 1856-1862 the funds, ranging from $30,000 to $75,000, were an "agricultural appropriation" paid directly from the Treasury.

The Commissioners of Patents, and others involved in the actions that led to the establishment of the Department of Agriculture in 1862, were strongly committed not only to research and experimentation for guidance of agricultural development throughout the emerging young nation, but also supported the concept of providing educational opportunities for those concerned with agricultural and industrial development throughout the nation. The first Morrill Act, providing for grants of lands to the states and territories for the establishment of educational institutions, was passed by the Congress and signed by President Lincoln on July 2, 1862. It is of interest to note that after a half century of uncertainty about federal support for agriculture these two important basic acts of Congress for development of American agriculture were passed and signed within a two-month period in 1862 when the country was in the midst of the Civil War. And the Homestead Act--which had special relevance to the westward movement of agriculture in the United States and which depended so heavily on the strengthened research and education base--also was passed in 1862.

3. Agricultural Research to 1900

Isaac Newton, Chief of the Agricultural Division of the Patent Office, was named by President Lincoln to be the first Commissioner of Agriculture, in charge of the U. S. Department of Agriculture. In developing the Department, emphasis was placed on the following functions: (a) collection and dissemination of statistical and other useful information relating to agriculture, (b) collecting and distributing seeds and plants for use in this and other countries, (c) answering inquiries of farmers and others on all matters relating to agriculture, (d) testing (by experiment) implements, cereals, seeds, and plants, (e) chemical analyses of soils, grains, fruits, plants, vegetables, and manures, and publication of results, (f) establishing professorships of botany and entomology, and (g) establishing an agricultural library and museum.

The department had six rooms in the basement of the Patent Office Building, formerly occupied by the Agricultural Division, and acquired possession of the property of that division, including the propagating garden at 6th Street and Missouri Avenue, N.W. The department also had assigned to it the tract of land between 12th and 14th Streets, from D Street to what now is Constitution Avenue, which was being used by the War Department as a corral for Army animals. The department acquired this tract in April 1865 when it was set up as an experimental farm. The present USDA buildings now occupy this area.

The initial work of the new department was handled by specialists to carry out selected lines of work: a botanist to serve as superintendent of the propagating garden, to lay out the Department grounds, and to plan its horticultural work; a number of chemists concerned primarily with analytical studies; entomologists concerned with systematic studies, the development of silk growing, and the development of a department museum; a statistician to develop improved statistical information on agricultural production as well as on exports from the United States; and a librarian.

A substantial part of the funds appropriated to the department were used for seed distribution, $115,000 out of $199,000 in 1867. This activity was criticized since many of the seeds distributed had not been tested in the regions to which they were sent and were not suited to the agro-climatic conditions. This criticism led to the substantial curtailment of the seed distribution function.

In the late 1860's, the Secretary of the Smithsonian Institution called attention to the increasing accumulations of botanical specimens from expeditions to Japan, the western U. S., and other areas, and suggested that these materials would be useful in developing agriculture west of the Mississippi River on lands opening to settlement under the Homestead Act. This led to the transfer of these materials to the Department of Agriculture with an understanding that a competent botanist would be employed to maintain the herbarium. This was the base for the National Herbarium of the Smithsonian Institution.

An outbreak of tick (Texas) fever of cattle in Illinois in 1868 led to the appointment of staff to study animal diseases. By 1884 the complex of animal disease problems had become critical and also Congress recognized the need for more research as well as better enforcement of the act passed in 1873 to regulate transportation of animals. This led to creation of the Bureau of Animal Industry by Act of Congress in 1884, the first scientific Bureau in the Department.

During the first 20 years of its existence much of the work of the Department was conducted by individuals concentrating on selected, specific problems, with continuing emphasis on silk production, the growing of cotton and other fiber crops in northern states, the production of sugar from corn and sorghum, the control of various insect pests and diseases, and on problems of forestry. The work on animal diseases, in entomology, subsequently in pomology, as well as other subjects or disciplines was handled under a growing number of divisions and offices. Much of the work of the Department was conducted in special laboratories or facilities acquired for that purpose.

There is limited reference to cooperative research between the U.S. Department of Agriculture and the state colleges or experiment stations prior to passage of the Hatch Act, signed by President Cleveland on March 2, 1887, providing appropriations for experiment stations in the states and territories. Earlier action or proposals, in the Carpenter and Holmes bills in 1882 and 1883, called for establishment of national research stations to be located at the colleges of agriculture but with the expectation that these would be under the control and management of the Department of Agriculture, in order to enable the department to fulfill the responsibilities for which it was established. The Hatch Act, as passed, established a new policy of relationship between the federal government and the states by furnishing funds to the states for agricultural experiment stations which were to be distinctly state institutions. The Hatch Act funds, administered through an Office of Experiment Stations within the Department of Agriculture, added an essential dimension to the agricultural research system of the United States by providing a network of research facilities to serve all types of farming throughout the country. Perhaps more important, the Hatch Act of 1887 furnished further evidence of the awareness of the Congress of its authorities under the Constitution--and its responsibilities--in furnishing support for systematic and sustained development of U.S. agriculture.

Another bill introduced by Mr. Hatch (HR 8191) on March 7, 1888, was designed to give the Department of Agriculture Cabinet rank. Favorable action was taken on this by the House and Senate in May and September 1888, and was signed by President Cleveland on February 9, 1889. The Hatch Acts of 1887, providing for the states to have their own agricultural experiment stations organized as departments of the land grant colleges, and of 1889, raising the U.S. Department of Agriculture to Cabinet rank, set up a nationwide agricultural research system for the U.S. with an authorized and recognized role of the federal government and the states.

It was intended that the state and national agencies for agricultural research would be linked together by (a) an Office of Experiment Stations in the Department of Agriculture to serve as a clearinghouse for research in the Department, the states, and throughout the world, and (b) an Association of Agricultural Colleges and Experiment Stations, in which the land grant institutions and the Department of Agriculture would work together for advancement of agricultural research and development throughout the country. In addition, the Department and state stations were also jointly concerned with the Association of Official Agricultural Chemists and the Association for the Promotion of Agricultural Science.

The passage of the Morrill Act of August 30, 1890, providing further federal funds for endowment of the land grant colleges, furnished additional strengthening of the national research system. Norman J. Colman was the Commission of Agriculture when the department was given Cabinet rank and he was named the first Secretary of Agriculture.

However, he served for less than one month, until March 4, 1889, when President Cleveland named Jeremiah Rusk as Secretary and Edwin Willits, President of Michigan Agricultural College, as Assistant Secretary. The selection of the Assistant Secretary from one of the land grant colleges helped to cement relations between the Department and the colleges. Assistant Secretary Willits was given responsibility for all scientific work in the department. The funding for experimental work did not increase materially during the Rusk administration and the plan of organization of the Department was not changed significantly by the end of his term of office in March 1893.

Secretary J. Sterling Morton, who served to March 1897, subscribed to the view that the functions of government should be kept at a minimum. During his administration there was no increase in annual appropriations for the Department although the budgets for scientific work were increased somewhat, particularly with regard to soils, grass and forage plants, and forestry. Also, the library received increased attention, and investigations in human nutrition were initiated during this period. In his report for 1896 Secretary Morton stated that over $1,700,000 out of a total appropriation of $2,584,000 for that fiscal year was spent on the technical and scientific work of the department, with about 1000 persons employed for such work.

4. The Agricultural Research Bureaus

It is generally recognized that the major thrust in strengthening the base for agricultural research in the Department occurred during the administration of Secretary James (Tama Jim) Wilson, who served from 1897 to 1913, under Presidents McKinley, Roosevelt, and Taft, a longer period than any other Cabinet officer in the history of the United States. Funding for the Department increased from $3,273,000 in 1898 to $24,742,000 in Secretary Wilson's final year, in 1913.

Research facilities were expanded through acquisition of the Arlington Farm, a tract of over 300 acres on the Virginia side of the Potomac River, in 1901 and the purchase of a farm of 475 acres at Beltsville, Maryland, in 1910 for use by the Bureau of Animal Industry for animal husbandry and dairy investigations. Secretary Wilson maintained the policy of keeping all scientific, technical, and clerical employees of the department within the classified civil service, including the Chiefs of Bureaus (except the Chief of the Weather Bureau, who by law was appointed by the President). This stabilizing influence, with recognition of the non-political status of personnel engaged in research, persisted for the first half of the twentieth century.

The organization of the Department was expanded and strengthened by setting up Bureaus to replace the various offices or divisions, etc., as the work of the department expanded in variety and extent. The Bureau of Animal Industry had been established in 1884 as the first Bureau in the department. The Weather Bureau had been transferred to the department from the Signal Service of the Army in 1891. In 1900 the Bureau of Plant Industry was established through consolidation of a number of previous divisions and offices. In 1901 the Bureaus of Chemistry, Soils, and Forestry replaced the former divisions, and in 1905, when the management of national forests was transferred to the Department of Agriculture from the Interior Department, the Bureau of Forestry was renamed the Forest Service. The Bureau of Statistics was established in 1902 as a combination of the previous Divisions of Statistics and of Foreign Markets. The Bureau of Entomology was created from the former division in 1903, and the Division of Biological Survey became a Bureau in 1904. The Office of Public Roads was also established in 1904 as a successor to the Office of Roads Inquiry.

The Office of Experiment Stations, which had been given responsibility for human nutrition research during Secretary Morton's administration, was expanded to include irrigation investigations in 1898 and drainage in 1902. The territorial experiment stations also were placed under the Office of Experiment Stations--Alaska in 1898, Hawaii and Puerto Rico in 1902, and Guam in 1908.

The consolidation of the research work of the Department into the respective Bureaus, together with the Office of Experiment Stations, facilitated communications and development of cooperative relations with the state experiment stations. Much of the work of the Department was conducted at federal field stations but a large and constantly increasing amount of research, particularly of the Bureau of Plant Industry, was conducted in cooperation with the state experiment stations. This prevailed for more than half a century, through 1953, when approximately two thirds of the funds of the bureau were expended in cooperative projects with the states. Plant introduction work, which had been established in the department in 1898, was extended and a system of worldwide explorations, propagation under quarantine, preliminary testing and maintenance, and distribution to federal, state, and private plant breeders, was expanded.

Livestock research was expanded and special attention was given to animal health, with special legislation in 1900, 1903, and 1905 relating to imports, exports, and transport of livestock to control contagious, infectious, or communicable diseases. The Meat Inspection Act of June 30, 1906, enabled the Bureau of Animal Industry to inspect meat food products intended for interstate commerce.

The demonstration farms and system of field demonstrations of improved practices to minimize the damage by the boll weevil in Texas developed, between 1904 and 1913, a widespread extension system in the southern states. This activity had financial support from the General Education Board as well as substantial appropriations from federal and state sources. This program, with men and women employed as state, district, and county agents, was introduced in the northern states in 1910, through the influence of the Office of Farm Management and, with cooperation of the agricultural colleges and farm organizations, spread rapidly. This was the base for the Smith-Lever Act of 1914 establishing the extenson service.

The Department of Agriculture engaged in a wide range of research and related activities during this period. These are presented in some detail in a number of publications (True, 1937, and Moore, 1967, and others).

5. National and Regional Research and Development Programs

Research conducted by the Department of Agriculture and the state experiment stations, to 1900, was largely by individual investigators, with cooperation based primarily on personal contacts and associations. One of the first efforts to conduct coordinated research programs involving scientists from the USDA, a number of state agricultural experiment stations, and also cooperating farmers, was the work on dry land agriculture in the Great Plains area (Quisenberry, 1977). The Great Plains is that part of the United States from the Canadian line south to central Texas, bordered on the east by the 98th parallel of longitude and on the west by the 5000 foot elevation along the eastern edge of the Rocky Mountains.

When the Hatch Act was passed by Congress in 1887 for establishment of agricultural experiment stations, only eight states had such stations and none were in the Great Plains. However, systematic experiments were in progress in Colorado, Kansas, and Nebraska. It was apparent from studies at these locations, and experiments conducted by USDA scientists at various locations in the region, that special practices for conservaton and use of moisture, for methods of cultivation and crop rotations, would be necessary for these low rainfall conditions. At the turn of the century M. A. Carleton, a cerealist and plant pathologist of the USDA, had research on cultural practices under dry land conditions in cooperation with the Nebraska and South Dakota experiment stations, on the XIT Ranch at Channing, Texas, as well as at Yuba City and Modesto, California. Investigations were initiated in 1901 under the leadership of John A. Widtsoe to determine the possibilities of farming without irrigation in Utah. Six dry land farms were organized in Utah in 1903, one of which was the Nephi station. This station has special significance since several of the early workers moved to places of leadership in U.S. agricultural research and education. W. M. Jardine went from Nephi to the USDA and then to Kansas State Agriculture College as Head of Agronomy, Dean of Agriculture and Director of the agricultural experiment station, President of the college, and subsequently Secretary of the U.S. Department of Agriculture. F. D. Farrell had essentially a parallel career pattern, going from Nephi to the USDA, then to the Dean of Agriculture and Director of the experiment station, and on to the Presidency of Kansas State College. P. V. Cardon went from Nephi to the USDA where he served at Moccasin and Bozeman, Montana, then to the Utah Agricultural Experiment Station where he served as Director before returning to the USDA as Head of the Forage Office, and subsequently Administrator of the Agricultural Research Administration. He later was named Director of the Food and Agriculture Organization (FAO) in Rome.

The USDA provided special funds for dry land research and E. C. Chilcott, agriculturalist and Vice-Director of the South Dakota agricultural experiment station, was hired by Carleton to take charge of the dry land research work. In 1906, the Office of Dry Land Agriculture (DLA) was established with Chilcott in charge and Carleton remained in charge of the Office of Grain Investigations (later the Office of Cereal Investigations). At the time of the establishment of the DLA it was stipulated that the DLA and CI offices were to work cooperatively.

After Chilcott joined the Bureau of Plant Industry to take charge of the dry land research work, he promptly called a meeting in Washington, D.C., in November 1905 to plan cooperative research, with representatives from various units of the Bureau of Plant Industry and from the agricultural experiment stations of North and South Dakota, Kansas, Nebraska, and Oklahoma. The stated purpose of the meeting was "to encourage and facilitate the coordination, systemization, and unification of all the cooperative experimental work to be engaged in by the Bureau of Plant Industry and the experiment stations and sub-stations of the several states included in whole or in part in the Great Plains area." Later it was agreed that Texas and Colorado should be included in the cooperative program.

The first meeting of the new Great Plains Cooperative Association was held in Lincoln, Nebraska, in June 1906 and such meetings were continued until World War I. This was the start of state-federal cooperation in agricultural research and set the pattern for similar cooperation on other regional and national problems confronting agriculture in later years.

The Association conducted research at the stations then in existence and also established new stations--by the states, the government, or cooperatively--with the experimental work done jointly by the state and federal workers. Stations were established at Hays, Kansas in 1901, Nephi, Utah in 1903, Amarillo, Texas in 1904, and North Platte, Nebraska in 1906. By 1910 there were twenty stations in operation and by 1916 there were twenty-nine. The Pendleton, Oregon station was started in 1928 and was the only DLA station not in the Great Plains.

The USDA Cereal Office was the chief cooperator at Amarillo, Texas, Archer, Wyoming, and stations in the Far West. The stations were distributed from Texas and New Mexico in the south to North Dakota and Montana in the north, with a few in the far west. Of the thirty stations eventually involved, all but six were in the Great Plains. All except Archer, Wyoming, and Nephi, Utah, were below the 5,000-foot level of elevation. All but three stations had an annual rainfall of 20 inches or less, while three of the western stations had less than 10 inches of rainfall per year. The DLA and cooperating SAES scientists worked on soil preparation and crop rotations while the cooperating USDA scientists concerned with cereal and forage crops, together with their state counterparts, conducted research to develop varieties better adapted to dryland conditions.

The range of problems in dryland farming that were studied included (a) crop sequence, (b) time, method, and depth of tillage in the preparation of the seedbed, (c) cultivation of fallow and row crops, (d) adaptation of varieties and strains of crops, and (e) adaptation of implements and methods to the varying combinations of soil and climate.

The research was conducted under rather austere conditions. At the prairie field stations, few buildings were constructed, usually a combination house and office, machine shed, barn, boarding-bunkhouse for laborers and, subsequently, field laboratory facilities. At each location there was a weather station and daily readings were taken on temperature, wind movement, humidity, and evaporation from a free water surface.

The work of the Office of Dry Land Agriculture continued until the late 1940's, when research on soil and water management in the USDA was reorganized and a number of the federal field stations were transferred to the respective SAES.

The work of the Office of Dry Land Agriculture and the cooperating SAES involved relatively simple field trials, utilizing the kinds of farm implements used by farmers, and was literally down-to-earth field experimentation. The several decades of research in dryland agriculture made an outstanding contribution to the development of productive agriculture in the Great Plains. It also served as an effective pattern for close federal-state cooperation in making maximum effective use of limited research resources.

6. Coordinated National Commodity Improvement Programs

The independent studies conducted by USDA scientists and research workers at the several SAES in the Great Plains region until the early part of this century were characteristic of research concerned with crop improvement. The rediscovery of Mendel's laws in 1901 stimulated interest in exploiting genetics and plant hybridization as a means of improving important field crops. Progress in these endeavors was limited until cooperative research, in which the USDA and SAES scientists participated fully, was established. The coordinated national and regional research programs for corn and wheat improvement serve as examples.

Corn Improvement

The early research in corn improvement was through selection of pure lines from open pollinated varieties, conducted by individual farmers, USDA scientists, and research workers at a number of SAES. The work on inbreeding and crossbreeding of selected inbreds traces back primarily to the research of G. H. Shull, working at the Station for Experimental Evolution of the Carnegie Institute of Washington at Cold Spring Harbor, New York, and of E. M. East at the Connecticut experiment station (subsequently at Harvard), started in 1905. Many other scientists were involved in the inbreeding and selection programs during the following two decades. Private individuals such as Henry A. Wallace (who became Secretary of Agriculture in the initial administration of Franklin Roosevelt in 1932), were prominent in this activity.

In the early 1920's, Dr. F. D. Richey of the Bureau of Plant Industry took the leadership in arranging conferences between state and federal corn breeders in the corn belt. Mr. Wallace and other private seed producers also participated in some of these meetings. The value of such conferences, providing for the interchange of viewpoints, as well as for exchange of genetic stocks or breeding lines, was evident to all participants. In 1925 the cooperative corn improvement program was established, involving the corn belt state experiment stations and the USDA, under the Purnell Act (Hayes, 1963).

Although Dr. Richey of the USDA was the coordinating leader of this cooperative program it was set up so that the initiative of indivudual workers was not suppressed. Annual meetings were held, frequently during the summer growing season when inbreds from various corn breeding programs were observed at other research stations. The principal mutual concern during the early years was the identification of the better double crosses for the many different environmental conditions under which the "hybrid corn" would be grown. Dr. H. K. Hayes states, "The free exchange of ideas and materials without doubt was responsible to a large extent for the progress in hybrid corn breeding and the wide acceptance of hybrid corn throughout the corn belt."

When it became apparent, in the early 1940's, that the hybrids selected for the corn belt were not suited for growing in the Southeastern United States a cooperative corn improvement project was set up for that region. The USDA again furnished the coordinating leadership of Dr. Richey, and hired corn breeders to be located in the cooperating experiment stations of North Carolina, Georgia, Mississippi, Kentucky, and Louisiana. Dr. Richey was located at the Tennessee agricultural experiment station. Out of this program soon emerged the "Dixie" hybrids that proved well-adapted to the growing conditions in the Southern states. As in the case of the corn belt program there was full provision for initiatives of the individual scientists, there was a close teamwork relationship between the USDA and SAES researchers, and the extended field testing of the emerging inbreds and new hybrids accelerated the development of hybrid corn in the South.

The cooperative corn improvement programs in the Corn Belt states, and in the Southern states, continued under the overall direction of Dr. M. T. Jenkins of the USDA until 1956, when Dr. G. F. Sprague assumed this coordinating leadership position. The production of new hybrids, and the production and distribution of seed was increasingly taken over by the private seed companies but the cooperative public service research, involving the USDA and the SAES during the first half of the century, provided one of the most important contributions to modern agriculture in the U.S.

Wheat Improvement

Cooperation of the USDA and the SAES is well illustrated by the research on hard red winter wheat improvement in the Great Plains (Reitz and Salmon, 1959).

The introduction of Crimean or Turkey wheat traces to about 1870 when productive varities were introduced into Kansas. Many separate lots of seed had been imported by 1900 and many strains were selected from the rather mixed introductions and distributed as improved varieties for commercial growing. Scientists of the USDA and the SAES continued the pure line or pedigree selection after the turn of the century but gave increasing attention to the crossbreeding of desirable varieties to introduce disease resistance, cold tolerance, milling and baking quality, and other characteristics. Interstate cooperation was an important part of the wheat breeding research. In the development of the variety Yogo, the original cross of varieties was made in Kansas in 1919. Part of the F_1 generation was grown in California, and the F_2 generation was grown in Kansas. The F_3 and later generations were grown at Dickinson, Fargo, and Mandan, North Dakota; Moccasin, Montana; and Akron, Colorado. The cross also was grown in bulk at Moccasin, Montana, and Yogo emerged as one of the strains selected at Moccasin. For many years it was a leading variety in Montana. In the development of Tenmarq, a leading variety in Kansas, selections from the cross P1066 x Marquis, made in Kansas, were tested in half a dozen states before the final selection was chosen and named Tenmarq.

These experiences, together with others, prompted the wheat breeders in the Great Plains states to establish a coordinated, cooperative program. A conference was held on November 8, 1928, at Manhattan, Kansas, where about 200 persons from the region met to discuss problems of wheat improvement, production, and marketing. The conference recommended that (a) more research be undertaken on soil fertility, plant diseases, and new problems growing out of changed practices in producing and marketing wheat, (b) that increased funds to support the work be provided, especially for the USDA, for coordinating wheat improvement work, and (c) that a permanent wheat research committee be appointed. The cooperative hard red winter wheat improvement program was set up at workers' conferences in 1929 and 1930, the first cooperative field trials were conducted in 1931, and a mimeographed report on the results was provided by the USDA coordinating leader in April 1932.

The hard red winter wheat improvement program was concerned with the development and testing of new varieties. The Office of Dryland Agriculture, in its cooperative state research program, was concerned concurrently with the closely allied work on tillage and crop rotations. The cooperative wheat program involved uniform nurseries for yield, winter hardiness, disease resistance, and also milling and baking tests--conducted at the Federal Hard Wheat Quality Laboratory located at the Kansas Agricultural Experiment Station at Manhattan. The USDA coordinating leader of the program reviewed the work annually in the field, beginning in May with the harvest in Texas and proceeding through Oklahoma, Kansas, Nebraska, South Dakota, and Montana as the wheat harvest progressed. This furnished an opportunity to observe the performance of varieties in farmers' fields in the respective states and also for interchange of current information with the cooperating scientists at the research stations in the region.

In addition to the coordinated hard red winter wheat improvement program in the Great Plains states, similar coordinated programs were established in the late 1920's and early 1930's for hard red spring and durum wheat breeding in the states of Minnesota, North Dakota, South Dakota, Montana, and Wyoming; for white wheat breeding in the western states of Washington, Oregon, Idaho, Utah, California, and Arizona; and for the breeding of soft red winter wheats in the eastern states. Dr. S. C. Salmon, who was on the staff of Kansas Agricultural College and later at the South Dakota experiment station, served as the USDA leader of wheat investigations until his retirement in 1946.

In the preparation of the article "Improvement of Wheat" for the 1936 Yearbook of Agriculture, Dr. J. Allen Clark of the USDA contacted the many workers involved in wheat improvement to receive suggestions for the article, and also for the further strengthening of wheat research in the U.S. It is of interest to note the comments of Dr. H. H. Love of the Cornell agricultural experiment station, who stated,

> "It seems to me that much valuable material is wasted or lost due to the fact that there is no thorough coordination between the different stations. I had urged that this be considered more than 10 years ago in the hope that materials produced at one station might be tested at other stations."

Similarly, Drs. R. P. Bledsoe and S. J. Hadden of the Georgia experiment station stated,

> "We suggest more extensive cooperation between and among the various state agricultural experiment stations, especially in the way of experiments having a regional application. We also suggest exchanges for testing."

The foregoing reactions were from research workers who were not then involved in the coordinated regional wheat improvement programs, although Dr. Love and the Cornell agricultural experiment station subsequently participated in the eastern regional wheat program.

Cooperative regional or national commodity improvement programs, involving the respective SAES and with coordinating leadership provided by a federal scientist, were established by the Bureau of Plant Industry for the other cereal crops, for flax, soybeans, alfalfa and other forage crops, and for some fruit and vegetable research in the period prior to World War II. These programs were generally regarded as highly effective and efficient not only by the participating research workers but also by the directors of the SAES, the leadership of the Bureau of Plant Industry, and at higher echelons in the USDA.

The cooperating SAES furnished the experimental fields, laboratories, offices, labor, and some operating budgets. Staff members of the experiment stations and colleges of agriculture participated fully in the research, conducting studies in their respective disciplines. The USDA furnished research staff, located throughout the region. For example, in the hard red winter wheat program a federal geneticist was located at College Station, Texas and a leaf rust specialist was stationed at Manhattan, Kansas. The regional coordinator, at Lincoln, Nebraska was also in charge of the station research on improvement of wheat and small grains. Joint employees were located in Oklahoma, Kansas, Colorado, and Montana. A similar situation prevailed in the cooperative corn improvement program in the corn belt states, with USDA personnel located in Iowa, Illinois, Missouri, Indiana, and Ohio. The work at the individual state experiment stations, whether directed by a USDA cooperating scientist or by members of the station staff, addressed primarily the problems of the farmers within the respective states. The USDA coordinating leader maintained an up-to-date awareness of the problems throughout the region and communicated these together with information on new research to the scientists in the region. Also, he was responsible for identifying, with the cooperating state research workers, the outstanding materials coming out of the research programs in the individual states, and including these in uniform nurseries which were assembled and distributed from the program headquarters. He also was responsible for collecting and analyzing the data from the participating stations and furnishing a summary report in time for analysis prior to the following planting season.

7. The Bankhead-Jones Act of 1935

The Bankhead-Jones Act of 1935 provided additional funds for federal grants. The Act stipulated that 60 percent of the funds be distributed on the basis of rural and farm population and that the remaining 40 percent should be a special research fund, to be used only for basic research. The major portion of the basic research funds were utilized to establish laboratories in the different regions of the country, to work on priority problems of the region as determined largely by the states. The laboratories were, however, set up and operated by the respective bureaus of the USDA and were designated as "US Regional Laboratories." The subject areas and locations of the laboratories were as follows:

- Plant, Soil and Nutrition Laboratory at Ithaca, New York
- Pasture Research Laboratory at State College, Pennsylvania
- Vegetable Breeding Laboratory at Charleston, South Carolina
- Poultry Research Laboratory at East Lansing, Michigan
- Soybean Research Laboratory at Urbana, Illinois
- Sheep Research Laboratory at Du Bois, Idaho
- Investigations of Plant Growth Regulating Substances at Beltsville, Maryland
- Investigation of Photo-period on Development of Plants at Beltsville, Maryland
- Salinity Laboratory at Riverside, California
- Animal Parasites Laboratory at Auburn, Alabama

- Swine Breeding Laboratory at Ames, Iowa

Although the laboratories were established to work on problems of special concern to the regions, and to serve the needs of the states, they were staffed and operated by the respective USDA bureaus and tended to be regarded as federal field laboratories. Also they were established just prior to World War II, at a time when research was redirected to meet wartime demands on agriculture, and basic research was relegated to the background. This caused constraints on funding which persisted after World War II, in part because of uncertainty whether the funding had to be limited to the budgets provided under the Bankhead-Jones Act or whether funds for regular appropriations for research on vegetables, forage crops, soybeans, etc., of the Bureau of Plant Industry, Soils, and Agricultural Engineering (BPISAE) or from other Bureaus could be utilized to supplement research at the laboratories.

8. Regional Utilization Research Laboratories

The continuing problem of agricultural surpluses in the 1920's and the 1930's, addressed by the Federal Farm Board and by the Agricultural Adjustment Act of 1933 (which was declared invalid by the Supreme Court), led to the decision by the Congress to direct the Secretary of Agriculture, in the Agricultural Adjustment Act of 1938, to establish four regional research laboratories, one in each major farm-producing area to conduct research to develop new uses and new extended markets and outlets for farm products. This research was to be concentrated on those commodities in which there were regular or seasonal surpluses.

The four regional laboratories were constructed at Philadelphia, Pennsylvania; Peoria, Illinois; New Orleans, Louisiana; and Albany, California. The construction costs were about $1 million each and the annual budgets were approximately the same level. The laboratories began operations in 1940 and work was barely underway before priorities were directed to wartime activities such as the commercial production of penicillin, sweetening agents from grains to replace sugar, development of synthetic rubber and rubber substitutes, production of dehydrated foods for the armed forces, and treatments to make cotton fabrics resistant to mildew and more suitable for military use. (A fifth utilization laboratory was authorized for Athens, Georgia in 1964.)

There was a continuing strong mutual interest on the part of the states and the federal government in the program of the four regional laboratories. The work was realigned after World War II to concentrate on the crop surpluses of the 1940's and 1950's. But, after more than two decades, the issue of whether the utilization research was effective in handling agricultural surplus commodities was still not resolved--as we entered the 1960's.

B. SAES

1. The Morrill Land Grant College Act of 1862

As companion to the Organic Act of 1862 which established the U.S. Department of Agriculture, Congress passed and on July 2, 1862, President Lincoln signed the Morrill Land Grant Act. The title of the Act reads: "An Act donating public lands to the several states and territories which may provide colleges for the benefit of agriculture and the mechanic arts." Institutions supported in part from funds by the grants have become known as Land Grant Colleges and Universities.

The Act, in addition to specifying the amount of land or land-script to be granted, and how the land or script or proceeds from its sale were to be managed, contained three landmark provisions that have had profound and far-reaching impact. The first is the prime object of the Act: "Each state may take and claim the benefits of the Act to the endowment, support and maintenance of at least one college, where the leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to agriculture and the mechanic arts in such a manner as the legislature of the states may respectively prescribe in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life." This carefully worded statement established for the first time as a national priority public funding of higher education of the "industrial classes," at that time mainly "agriculture and the mechanic arts," i.e. essentially everyone. Thus, over the intervening years, the Land Grant Colleges have been characterized as the "People's Colleges" dedicated to higher education opportunities for all the nation's citizens.

The second and third precedents are contained in section 5 of the Act which authorizes "A sum not exceeding ten percent of the amount received by any state may be expended for the purchase of lands for sites or experimental farms whenever authorized by the respective legislatures of said states," and "Each state shall make an annual report regarding the progress of the college, recording any improvement or experiments made with their costs and results, and other such matters, including state, industrial and economical statistics as may be supposed useful, one copy of which shall be transmitted by mail free, by each and to all other colleges which may be endowed under the provisions of this Act, and one copy to the Secretary of the Interior." (This copy now goes to the Secretary of Agriculture.)

The authorization to purchase lands for "sites or experimental farms" was recognition of the linkage between research and higher education--i.e. research generates the science used in the classroom, and that applied research was a significant part of the need. The reporting requirement became an important force in binding the land grant colleges to each other and to the federal government. These bonds have been strengthened over the years and the system created has become a model upon which many other federal-state relations have been built.

2. The Morrill Act of 1890 and Subsequent Amendments

The so-called second Morrill Act, of 1890, carried two landmark provisions: (a) "for a more complete endowment and support of all of the Morrill Land Grant Colleges," and (b) for states to utilize the land grant and other endowments to support separate land grant colleges for black citizens.

The former set yet another principle--that endowment and support needed to be expended from time to time as the nation's and the land grant colleges' needs grew. The latter gave recognition, perhaps for the first time, that higher education for certain disadvantaged minorities required special treatment. That special treatment has evolved up to its present form of civil rights and equal opportunity legislation and regulations.

Additional endowments were provided by the Nelson Amendment of 1907 and, in 1935, the Bankhead-Jones Act authorized regular appropriations for the land grant colleges' instructional programs.

This set of endowments and appropriations has had a profound effect on the land grant colleges and on higher education in general. Beyond the bonding together of the land grants and the linkage to the federal government, the model of federal-state collaboration has been extended in a major way to science and education in general, including the sea-grant program, the health professions, and, very recently, to energy.

In the land grant institutions themselves, the infusion of federal funding has given impetus to a number of developments. In particular, they provided (a) for the expansion of the Department of Agriculture at each college into a School of Agriculture with its six traditional departments: agronomy-soils, horticulture, animal husbandry, dairy husbandry, poultry husbandry, and agricultural economics; and for greatly strengthening the four supporting sciences: physics, chemistry, botany, and zoology; (b) for the expansion of the Department of Mechanic Arts at each college into a School of Engineering with its four traditional departments: mechanical, civil, electrical, and chemical, and for strengthening the supporting sciences of advanced mathematics, physics, and chemistry; (c) for strengthening the teaching of English throughout the colleges as a whole; (d) for the establishment and support of certain black land grant colleges; and (e) for increasing the salaries of the teachers in many of the colleges and in preventing decreases in others. More particularly, the use of these funds marked a transition of the teaching dimension from a period of doubt and uncertainty to a period of growth and development, with the subsequent extension of service to the people.

3. Formalizing the Research Element--The Hatch Act of 1887

Passage of the Hatch Act of 1887 was the beginning of the institutionalization of research in the land grant system. Although 14 states had begun the operation of tax-supported agricultural experiments by 1885, most were operating on meagre and often insecure funds. The prospect of federal funds authorized in the Act brought new hope--hope that was realized in the appropriation process. The system has grown steadily over the years to encompass every state and territory, with ever-increasing ratio of state to federal funding, even though the required match is basically one-to-one.

The purpose of the Act was, and remains: "To promote scientific investigation and experiments respecting the principles and applications of agricultural science, there shall be established, under the direction of the college or colleges or agricultural department or colleges in each state or territory, a department to be known and designated as an agricultural experiment station."

The "object and duty" of these stations is "to conduct original researches or experiments on the physiology of plants and animals; the diseases to which they are severally subject with the remedies of the same; the chemical composition of plants at their different stages of growth; the comparative advantages of rotative cropping as pursued under a varying series of crops; the capacity of new plants or trees for acclimation; the analysis of soils and water; the chemical composition of manures, natural or artificial, with experiments designed to test their comparative effects on crops of different kinds; the adaptation and value of grasses and forage plants; the composition and digestibility of the different kinds of food for domestic animals, scientific and economic questions involved in production of butter and cheese; and such other researches or experiments bearing directly on the agricultural industry of the United States as may in each case be deemed as advisable, having due regard to the various conditions and needs of the respective States and Territories."

The Act paved the way for the union of the 1862 land grant college teaching programs and the newly created experiment stations and thus for each to support the other. Since the Act pre-dated the second Morrill Act, there was no parallel fallout to the 1890 land grant colleges, a matter that was finally addressed in Title XIV of the Food and Agriculture Act of 1977.

The "object and duty" section of the Act provides an essentially open-ended charter for the State Agricultural Experiment Stations. After generalizing a range of problem areas, the section ends with language that authorizes any given Station to engage in research "bearing directly on the agricultural industry of the United States" while at the same time permitting confinement to take account of the "various conditions and needs of the respective States and Territories." By implication, the language suggests that the Stations' programs, as they address respective conditions and needs of the several states and territories, aggregate to address the needs of the agricultural industry of the nation. But it is equally implicit that the first "duty" of each Station was that its program address the problems of the agricultural industry of the state. It was not until the passage of the Research and Marketing Act of 1946 that the State Stations Charter was formally extended to a regional and national context.

As with the Morrill Act, the Hatch Act requires regular reporting to the federal government, thus building further the federal-state partnership in research and education. The partnership spirit has been facilitated over the years through the coordinative role played by the federal office administering the federal funds in the programs of the Stations. Although at times the institutional relations between the federal and state counterparts has been under some stress, the working relations between the federal and state scientists has generally been open and harmonious, based as they are on professional peer relationships.

4. The Smith-Lever Act of 1914--Formalizing the Extension Function

A number of methods for extending research information to users developed soon after the establishment of the research function in the land grant colleges. These varied from state-to-state and included--in addition to personal conferences and correspondence --Farmers' Institutes, agricultural trains, the Farmers' or Farm and Home Week, and transfers of new materials and practices directly from the station scientist to the farmers' fields.

There was considerable concern on the part of the Office of Experiment Stations with respect to the increasing use of funds from the Hatch Act for printing, correspondence, administration, and miscellaneous purposes, including demonstrations and extension. In 1909 OES Director A. C. True issued a directive that as of July 1, 1909, all charges for extension work and printing of compilations would be eliminated from the Hatch Fund Account. He stated that this action was not intended to hinder the development of extension work, the value of which he greatly appreciated, and the OES would do anything in its power to aid the agricultural colleges in securing funds with which to thoroughly organize and develop extension work along the lines of agriculture and country life.

Mention was made earlier in this report, pg. 10, of the demonstration farms and system of field demonstrations of improved practices, led by Seaman Knapp, to minimize damage by the boll weevil in Texas, between 1904 and 1913, that evolved into a widespread extension system in the southern states. This activity, financed by the General Education Board together with federal funds appropriated by the Congress in 1904 and state sources, with men and women employed as state, district, and county agents, was introduced into the northern states in 1910. The states built the program on the concept of local grower and business support, and the Office of Farm Management exerted influence in this endeavor, with cooperation of the agricultural colleges and farm organizations. By 1910 five states had a formal statewide program and by 1912 most other states had adopted the model. This served as the base for the Smith-Lever Act which was passed on May 8, 1914, and institutionalized the model on a national level.

It is of interest to note the time span on the establishment of the colleges through the Morrill Act of 1862, the addition of the experiment stations through the Hatch Act of 1887 (25 years later), and the addition of the extension service through the Smith-Lever Act of 1914 (25 years later). The education, research, and extension functions of the land grant colleges and universities emerged in response to public awareness of the needs for these services. The tri-functional federal-state partnership persists to the present--as a highly successful and responsive system of support to the nation's most basic industries--provision of food, clothing, and shelter.

5. Extending the Research Base--Additional Legislation to 1940

Three additional Acts impacting the State Experiment Stations were enacted in the 1900-1940 period. The Adams Act of 1906 stressed basic research on production in all fields. The Purnell Act of 1925 brought emphasis to home economics and rural sociology, as well as reinforcing production and marketing of agricultural products. That Act also dealt with federal/state cooperation in research, a matter that had not been emphasized up to that time in legislative terms. And the Bankhead-Jones Act of 1935, as discussed under the section on the USDA, highlighted genetic and environmental studies of crops and animals, as well as on soils and water.

6. USDA and SAES Relationships

There were numerous basic issues to be resolved in the evolution of the national agricultural research system as it developed to the World War II period. It is of interest to note that although early leaders of this nation, including Washington and Jefferson, were personally involved in extensive farming operations and in experimentation, they did not move aggressively for federal support for agricultural development. In fact, Jefferson opposed this with the view that the Constitution did not provide for such support and that federal involvement should be held to a minimum.

The acts of Congress in 1862 establishing the U.S. Department of Agriculture and providing land grants to the states and territories for colleges of agriculture set the basic pattern for federal support for agriculture and also for both a centralized or nationalized function as well as the dispersed capabilities at the state and territorial levels. The subsequent acts of Congress, in 1887 furnishing funds to the states to establish agricultural experiment stations, and in 1889 elevating the status of the USDA to Cabinet level, provided for a further commitment of the federal government to agricultural development that also reemphasized the concept of a strong national capability and a strong state/territorial capability for agricultural research. The initial concerns about the potential dominance of the USDA over the Hatch Act grant funds was minimized by establishment of the Association of American Agricultural Colleges and Experiment Stations in

1887 (now the National Association of State Universities and Land Grant Colleges). A basic principle of the Hatch Act legislation of 1887 was that the Secretary of Agriculture should be responsible for approving projects to be investigated, and for preventing duplication of work among the states. The Office of Experiment Stations was established on October 1, 1888, to represent the Secretary of Agriculture in his relations with the stations. In 1891 provision was made in the charter of the Association of American Agricultural Colleges and Experiment Stations for a delegate representing the Office of Experiment Stations and also a general representative of the USDA, often the Assistant Secretary of Agriculture.

The participation of USDA representatives in meetings of directors of agricultural experiment stations continued and was expanded after the research bureaus were established in the USDA. During the 1940's, representatives of the USDA research bureaus attended the annual regional meetings of the state experiment station directors, providing an opportunity for exchange of views with respect to priority problems and programs, and to identify specific areas where research of mutual interest should be strengthened or modified.

The Assistant Secretary of Agriculture, in the first years after the department was given Cabinet status, was usually given responsibility for research. Frequently this position was held by an individual from a land grant college or state agricultural experiment station. Alfred C. True served as Director of the Office of Experiment Stations from 1893 to 1915 and was Director of the States Relations Service from 1915 to 1923. Another distinguished and highly respected official was James T. Jardine, who served as Director of Research of the USDA and also as Chief of the Office of Experiment Stations for many years, through the 1930's.

There was a constant interpretation of the relationships between the USDA and the state stations, with concerns expressed with respect to the divergent policies of the several USDA bureaus in their cooperative relations with the state experiment stations, the relationship of the federal field stations to the work of the state agricultural experiment stations in the states in which they were located, the direction and guidance of research workers employed and paid jointly by the USDA and the states, and other matters. Many of these issues were resolved through the development of cooperative memoranda of understanding.

Some further centralization or consolidation of the work of research in the USDA occurred on December 13, 1941, when Secretary Claude R. Wickard reduced from 17 to 8 the number of agency heads reporting directly to the Secretary, by grouping the bureaus and agencies into administrations. The Agricultural Research Administration, headed by Dr. Eugene C. Auchter, former Chief of the Bureau of Plant Industry, included the Bureaus of (a) Agricultural Chemistry and Engineering, (b) Animal Industry, (c) Dairy Industry, (d) Entomology and Plant Quarantine, (e) Home Economics, (f) Plant Industry, and the Office of Experiment Stations. The Agricultural Research Administration was primarily a conduit for the bureaus in their relations with the Secretary and the ARA, with a limited staff that was not directly involved with research and soon lost touch with activities in the extensive field and laboratory programs, had only a limited "coordinating" role in the planning and assessment of research. At best, the ARA staff identified projects of one bureau or agency that tended to duplicate or relate to research in another bureau or agency.

With the formation of the Agricultural Research Administration the relationship between the ARA Administrator and the Chief of the Office of Experiment Stations continued to be somewhat uncertain and this was the subject of discussion at meetings of the experiment station directors throughout the 1940's.

The USDA Miscellaneous Publication No. 904, issued in May 1962 in observence of the USDA-land grant college centennials of 1962, entitled State Agricultural Experiment Stations: A History of Research Policy and Procedure, presents an excellent sequential review of the federal-states relations. This publication states, pg. 121, that following passage of the Adams Act, which was signed March 16, 1906, by President Theodore Roosevelt, "cooperation" took on its modern meaning: the never ending search for adjustments between the stations and the Department as to the division of responsibility for research in the states. Although there were continuous interchanges between representatives of the USDA and the Experiment Station Committee on Organization and Policy (ESCOP) through the first four decades of the 20th century, there was a continuous strengthening of cooperation at the working level as reflected in the close association of USDA and state scientists in regional and national research programs such as those in dryland agriculture and the national commodity improvement research, described previously.

II. CHANGES IN THE 1945-1960 PERIOD

A. USDA

1. Reduced Emphasis on Production Research

At a meeting of USDA research personnel at the Plant Industry Station auditorium at Beltsville in 1951 Secretary Charles F. Brannan discussed the range of functions and responsibilities of the Department other than research. He gave special attention to the problems of storage and distribution of surplus agricultural commodities. Following his presentation a visiting European scientist commented, "The United States has a problem, but it is a beautiful problem."

The accumulation of agricultural commodity surpluses, following World War II and again following the Korean War, created some negative sentiments toward agricultural research, particularly that which was considered as production oriented. In much the same way as research was retitled in the early 1940's to indicate its relationship to the World War II effort, agricultural research in the early 1950's was realigned as "farm research" to minimize the image that agricultural research was exacerbating the continuing problem of commodity surpluses.

In recognition of the importance of maintaining a sustained capability in production research, to increase efficiency of production, and also to ensure against serious losses from outbreaks of diseases and insect pests, close relationships were developed by USDA and SAES scientists with such farmer organizations as the National Association of Wheat Growers, Oregon Wheat League, Cotton Council, and other similar associations concerned with other cereals, citrus, tobacco, soybeans, etc. This improved liaison was effective in increasing support for research on oats, to meet the series of diseases that emerged to attack the new oat varieties developed and released regularly during the 1940's, to minimize the losses from bunt or stinking smut that were ranging up to 50 percent in the western wheats, and the prompt response by USDA and SAES scientists to the threat of the Mexican fruit fly which was discovered over the border in southern California in the early 1950's. In spite of the efforts to strengthen production research in the department during this period it was not possible to develop the capability to accelerate wheat improvement research in time to meet the outbreak of the virulent race 15-B of stem rust which destroyed 65 percent of the durum wheat crop in 1953 and 75 percent of the crop in 1954, in addition to causing widespread damage in the hard red winter wheat and hard red spring wheat crops during those years. However, the working relationships developed between the federal and state research workers and the respective farmer or commodity associations during this period had a very beneficial stabilizing effect on the cooperative research programs.

The associations were helpful in obtaining financial support for the SAES from the respective state legislatures and also for the USDA bureaus and branches through their relations with the House and Senate committees.

The close cooperation that prevailed is indicated by the procedures for planning and conduct of the research in the critical problem areas. The Oregon Wheat League took the initiative in urging that research be strengthened to meet the increasingly critical bunt problem. This was called to the attention of the states in the region and also of the Bureau of Plant Industry, Soils, and Agricultural Engineering (BPISAE). The latter organization requested that the scope and nature of the research be planned jointly by the staff of the state stations concerned, working with the BPISAE wheat research staff in the region. Similarly, when the threat of the Mexican fruit fly appeared, the California Citrus Exchange took initiatives in requesting the Entomology Research Branch of the USDA to strengthen research on this problem. The USDA scientists met with the staff of the Citrus Experiment Station at Riverside, California, with research staff of the Texas experiment station, and also with USDA personnel and Government of Mexico officals involved in the cooperative citrus research in Mexico, to design the research and related control programs. The additional staff employed by the increased funds to the USDA for the above programs, and for the expanded wheat research in the Great Plains area, were located almost entirely at the cooperating state agricultural experiment stations.

2. Realignments in Soil and Water Research

There was a growing appreciation, on the part of both the USDA and SAES scientists, that much of the work that had been conducted cooperatively through the Division of Dryland Agriculture and the Division of Irrigation Agriculture of the USDA had reached a point in the mid-1940's--after operating for four decades--where substantial realignment was desirable. Steps were taken to transfer a number of the federal field stations to the state experiment stations of the respective states, and to assign the USDA scientists, where possible, to cooperative investigations in the state experiment stations. From January 1951 to September 1962 Department research was discontinued at 33 federal field stations that were closed up or transferred to the states. A few of the major stations, such as the Northern Great Plains Field Station at Mandan, North Dakota, and the Southern Great Plains Field Station at Woodward, Oklahoma, were retained by the USDA. Also, some of the federal field stations did not fit into the state experiment station networks, so these were either closed or retained in the federal structure.

Some new activities in soil and water management research were initiated during this period, including research cooperative with the Bureau of Reclamation and the SAES to determine commodities and farming systems suited for the Columbia Basin, where irrigation water was made available from the Grand Coulee Dam. Similarly, research on crops, soils, and irrigation was undertaken at the request of the Farmers' Association of the Imperial Valley of California, with a research station established at Brawley in 1947. These two area research projects reflected the continuing interest of growers and agricultural leaders in support from the USDA in multi-commodity and multidisciplinary research programs that required substantial research staffing and investments.

In addition to the shifting of staff and resources from the federal field stations for dryland and irrigation agriculture in the west, the BPISAE also strengthened the cooperative research at SAES in the eastern U.S. One example is the research initiated with the North Carolina agricultural experiment station to give attention to corn production practices--including adapted hybrids, plant populations per acre, soil fertility and water management practices, and other interacting factors in producing this crop. This research had a significant impact not only in North Carolina but in other southern states in accelerating the acceptance and growing of the corn hybrids emerging from the cooperative regional corn improvement research program initiated by the USDA and the southern states a few years earlier.

Another major adjustment in soils research was the transfer, in 1952, of the research that had been conducted by the Soil Conservation Service, from the time the SCS was established in 1935, to the BPISAE, where it was combined with the similar but more extensive soil and water management research of the USDA. At the same time, the responsibility, staff, and other resources of the basic soil survey (The Division of Soil Survey) were transferred from the BPISAE to the Soil Conservation Service. This permitted the basic surveys to be more intimately associated with the land use capability classification of the SCS and resulted in a closer working relationship of those concerned with soil classification with the soil conservation districts and associations.

A proposal for reorganization of the soils research in the USDA, by Dr. F. W. Parker, Assistant Chief of the Bureau of Plant Industry, Soils, and Agricultural Engineering (BPISAE), to the Chief of that Bureau in 1952 has relevance to the current OTA study since the present organization of USDA research tends to follow rather closely that 1952 proposal. Dr. Parker suggested a soils research organization that would provide for a regional director for the eastern U.S. (humid region) and a regional director for the western U.S. (dry land and irrigated agriculture). This was agreed upon and Dr. L. B. Nelson, later with the TVA, headed up the eastern regional work from Beltsville. Dr. O. J. Kelley headed the western region, first from Beltsville and later with offices at Colorado State University, at Ft. Collins. The Eastern Section covered the 31 Eastern States. The Western Section included the 17 Western States and Hawaii, essentially the work of the old Dry Land Agricultural Division and the Irrigation Agriculture Division which were combined in the late 1940's. At that time the Western Section was responsible for all of the Soil and Water Research of ARS in the 17 Western States except that at the Salinity Laboratory.

A second major aspect of Dr. Parker's proposal was the setting up of "area coordinators," to cover several states. This became a matter of strong vigorous disagreement, with the Chief of BPISAE opposing the area coordinator concept on two basic grounds, (1) the designation of a USDA soils "coordinator" for a two or three state "area," to essentially second-guess the directors of the SAES or the heads of Departments of Agronomy, Soils, or Irrigation in a state experiment station would most likely, and properly, be resented unless the federal scientist was fully and actively engaged in research of mutual interest and a part of the station scientific complement, and (2) it seemed a questionable use of highly competent soil scientists to assign them to area coordinator roles where they would undoubtedly be less effective as working field scientists. The soils research was not set up with the area coordinator pattern during the time it was in the BPISAE.

The organization pattern for soils research, with area representatives, was put into effect after Dr. Parker left the USDA to join the U.S. Foreign Aid staff in India, and following the reorganization of 1953 when the Soils Research Branch and Agricultural Engineering Research Branch were placed, together with the Agricultural Economics Research Branch, under Dr. Sherman Johnson as director for the group.

Soil and water conservation research was again reorganized in 1961 when the then Soil and Water Conservation Research Division was realigned to consolidate the previous watershed technology research branch and the eastern and western soil and water management branches under seven geographic branches which encompassed the entire program. National subject-matter specialists were appointed to give national leadership and to serve as counsel to the division director and each of the branches had investigation leaders, most of whom were active scientists, who gave regional leadership to particular subject-matter efforts such as wind erosion, water conservation in dryland agriculture, irrigation water management, etc. These Staff Specialists were responsible for the technical components of all programs, highly respected scientists who worked with both the SAES and ARS staff in developing their research programs. One person at each location served as administrative head for the program.

Given the scope of program encompassed in the division, and the number of locations and scientists involved, this organizational pattern worked rather well and retained a balance of national and regional technical leadership in the design and direction of program. It is of interest to note that Mr. T. W. Edminster, one of the principal architects of the 1972 reorganization, later became the director of that division and still later administrator of the Agricultural Research Service.

3. Geographic Shifts in U.S. Agriculture

Cotton in the West

Scientific and technological advances that occurred in the U.S., together with pressures for expanding production of various crops, caused substantial geographical and structural changes in commodity production and farming systems by the end of World War II. The development of the mechanical cotton picker, the advent of selective herbicides, together with the earlier research to develop adapted cotton varieties, combined to increase cotton production in California, Arizona, and New Mexico during the war years. Following World War II there was substantial pressure from agricultural leaders and Congressional representatives from the southern states to increase research to improve cotton production in the South. Some attention was given to this, through projects to study mechanization, improved ginning, genetics and breeding, as well as insect control. However, it was apparent that the comparative advantage for cotton production had shifted westward and other agricultural enterprises were necessary for profitable farming in the South.

Livestock in the South

Since it seemed feasible to provide for year-around forage crop production in many of the southern states it was apparent that livestock production could be expanded in this region. USDA funds were increased substantially for research on improvement of grasses and legumes, on seed production, and on pasture management. Also, research was expanded on oats and other small grains, to increase supplies of feed grains for livestock in the South. This research, together with the earlier regional program on corn improvement and the research on cropping practices initiated in cooperation with the North Carolina and other southern experiment stations, were dominant factors in improving the agricultural economy of the southern U.S. following World War II. In this situation it was primarily the conceptual leadership of USDA personnel, including Drs. M. A. McCall, Assistant Chief of the BPISAE, E. A. Hollowell in forage crops, and K. S. Quisenberry in cereal crops who furnished the initiatives and the follow-up leadership in planning, with the state counterparts, the strengthened and expanded cooperative programs.

A subsequent research development of special significance was the sterility principle for eradicating insect pests. The evolution of this principle by Dr. E. F. Knipling and his associates, the pilot stage evaluation of the process for eliminating the screw worm on the island of Curacao, and the later successful eradication program in Florida was effective in saving many millions of dollars annually from losses to this livestock pest.

Plant Introduction Nationwide

The action taken to rejuvenate and reorganize the system and facilities for plant introduction, beginning in 1948, did not necessarily provide for geographic shifts of agriculture in the U.S. but was instrumental in strengthening research resources in the various agricultural regions. This also provides an excellent example of the mutual respect for initiatives, and responsiveness, on the part of cooperating federal and state research workers during this time. Dr. R. E. Buchanan, Director of the Iowa agricultural experiment station, took the initiative in 1948, in a meeting with BPISAE staff at Plant Industry Station, Beltsville, to call attention to the lack of support for foreign explorations for new plant germplasm; the lack of systematic procedures for observation, evaluation, and maintenance of selected germplasm stocks; and the lack of availability of such potential breeding materials to state, federal, and private plant breeders throughout the United States. Out of this discussion evolved a plan for continuous basic funding for foreign explorations, at a level to permit up to two or three extensive foreign tours annually. It was agreed that these would be planned and arranged by the USDA staff but the commodities or plant resources to be searched for would be determined jointly by the federal and state scientists, and state experiment station personnel as well as USDA scientists would be involved in the field surveys.

In order to provide for effective field testing and maintenance of materials regional centers were established at Experiment, Georgia; Geneva, New York; Ames, Iowa; Pullman, Washington; and Sacaton, Arizona. In addition, it was agreed that a national seed storage laboratory should be established to maintain collections of small samples of highly selected germplasm materials. After careful consideration of alternative locations, this seed storage laboratory was located on the campus of the Colorado Agricultural Experiment Station, at Fort Collins.

Parallel with the developments in BPISAE, the State Agricultural Experiment Stations in each of the four regions initiated regional projects which were directly linked to the regional centers of BPISAE. These regional projects have been continued and strengthened to the present time and constitute an effective federal-state partnership in assuring collection, testing, and maintenance of a wide range of genetic materials undergirding the total plant breeding efforts of the system. Many view the state's collective input to the total effort as being both essential and perhaps of equal importance to the federal input while at the same time acknowledging the lead role of the federal partner in terms of foreign explorations.

Plant introduction work was one of the earliest functions of the federal government. It has been of critical importance in the evolution of nearly all important economic crops in American agriculture, and must be a continuing part of the national agricultural research system. The revitalizing of the plant introduction program, with greater participation by and services to the SAES was completed during the 10 year period ending in 1958 when the seed storage laboratory at Fort Collins was completed. This was a cooperative venture, involving not only the initiative of Dr. Buchanan, but the responsiveness of the USDA, and also the support of such organizations as the American Association of Wheat Growers, the American Society of Agronomy, and other groups that recognized the essential nature of this program.

Expansion of Soybean Production

The expansion of soybean production in the U.S., to its present position in the U.S. agricultural economy, also traces to steps taken primarily after World War II. The earliest introduction of soybeans to the U.S. is recorded as 1889 when W. P. Brooks, of the Massachusetts Agricultural Experiment Station, which was helping to establish an agricultural college in Hokkaido, brought a number of varieties from Japan.

In 1898, the department introduced large numbers of soybeans. Before this time there were not more than eight varieties, with limited adaptation to U.S. growing conditions, grown in this country. Some of the early breeding work in soybeans was conducted by C. P. Piper and W. J. Morse of the USDA Experiment Farm at Arlington, Virginia, prior to 1910. A resume of the soybean research program has been suppplied by Dr. R. W. Howell, Head of the Department of Agronomy of the Illinois Agricultural Experiment Station. He joined the program in 1952 and was directly involved for more than a decade.

Dr. Howell considers the USDA/SAES cooperation in soybeans a textbook example of federal/state cooperation. There were valuable precedents from cooperation of the cereals and forage divisions of the USDA with the SAES, but the national coordinated soybean improvement program exemplified continuity of this cooperation after World War II. The state agricultural experiment stations provided facilities, labor, and operational support. In turn, they benefited from the presence of USDA scientists on their campuses. The USDA provided staff (for many years most soybean researchers were federal employees) and operating funds, but did not have to invest in facilities or in their maintenance. Improved varieties and other technology which resulted made possible the spectacular growth in soybeans in the past three decades.

A key element in the cooperation was the series of strong and respected USDA project leaders. W. J. Morse, USDA's "soybean man" from 1907, was the project leader when the national coordinated program was organized in 1936. He was succeeded in 1949 by Martin Weiss, who in turn was replaced by Herbert W. Johnson in 1954. After a brief interval in 1964-65 when R. W. Howell was investigations leader, Billy E. Caldwell was the leader from 1966 until the reorganization of the USDA in 1972. Weiss, Johnson, and Caldwell were all plant breeders. These men were not only the designated leaders of USDA research, but were recognized as de facto national "investigations leaders."

The number of people in soybean research grew steadily after the regional program was established in 1936 and by 1954 had about 15 scientists. There were memoranda of understanding with about 24 states, all of which had one or more collaborators participating in the program. A few had active soybean breeders and/or pathologists, but many state programs were limited to growing regional test material.

Of the early soybean workers, Dr. C. M. Woodworth of Illinois was notable. Dr. Woodworth came to the University in 1920 to establish an active soybean genetics and breeding program. He was the first soybean geneticist and bred the 'Illini' variety, announced in 1929. A few years later he introduced the variety 'Chief.' In 1932 he published a list of about 35 genes in soybeans, and chromosome charts identifying three linkage groups.

The National Cooperative Program in a very real sense had its foundations in Dr. Woodworth's program. The variety 'Lincoln,' the first variety to result from the program, was selected from a cross made by Dr. Woodworth years earlier. After the Cooperative Program got under way, the variety development work for Illinois and other states remained for many years almost exclusively the responsibility of federal employees. The Illinois station contributed significantly through basic genetics studies carried on by Professor Henry Hadley, who joined the faculty in 1957, and Professor Theodore Hymowitz, who came in 1967. Both are still on the staff.

The Regional Soybean Laboratory, established in 1938 at the Illinois Agricultural Experiment Station, has played a prominent role in soybean improvement research since its inception.

The research and development that led to soybean production increase was gradual rather than abrupt. W. B. Allington and D. W. Chamberlain, both pathologists, had joined the Soybean Laboratory during the war years. One of their early achievements was the identification of the causative organism of brown stem rot, Cephalosporium gregatum. Dr. Edgar Hartwig moved to Mississippi and started the soybean breeding program at Stoneville, also in the middle forties.

Many young scientists came into the program during Weiss's leadership and shortly thereafter. These included not only Johnson and R. D. Osler (who stayed only about 2½ years and has since been in Mexico) but also R. L. Bernard at Urbana and C. A. Brim at Raleigh. Brim recently retired and is now a soybean breeder for Funks International.

Dr. Howell states that he did not detect any diminution of effectiveness of the federal-state relationship after the reorganization of 1953, but notes that he had been with the soybean project only one year, since 1952. In fact, he suggests that the reorganization of 1953 put the soybean investigations in a more conspicuous organizational framework and probably contributed in its way to the expansion of soybean programs.

The really big increase in soybean production research occurred in the 1960's. Many stations employed physiologists to work on soybean problems for the first time. Pathologists and breeders were employed, and weed scientists and agricultural engineers were added. The USDA staff expanded dramatically, and practically all of the increased personnel was located on University campuses.

In general, the relationship of the USDA people and the stations continues to be very good. It is not what it was in earlier days when the numbers of people involved were fewer and when there was an organizational framework which fostered a sense of unity. Yet carrying on the tradition which was established by the pioneers of soybean research there continues to be an openness and sense of cooperation which are inspirational.

In 1961, there was just one commercial breeder of soybeans. (Coker, North Carolina) However, with the signing of Public Law 91-577 91st Congress S3070, December 24, 1970, there was an immediate increase in the interest of commercial breeders. This law was known as the Plant Variety Protection Act, providing patent protection for the developers of new varieties that reproduce through seeds. At the present time there are a total of 72 soybean geneticists and breeders, equally divided between the public and private sectors.

The role of the public sector, including USDA, is to provide the basic information with which commercial breeders work but--because of lack of facilities and capital--the private breeders are not in a position to obtain on their own. Examples of this are the identification of nematode resistance, disease resistance in general, and photosynthetic capabilities. The development of new varieties is largely in the hands of the private sector breeders, but occasionally new varieties may result as a consequence of the more basic work performed by USDA and SAES.

4. The Research and Marketing Act of 1946

The Research and Marketing Act of 1946 was initially designed to increase marketing research in the Department of Agriculture. However, by the time the bill was enacted, it also contained substantial sums for research on utilization, quality improvement, and other areas of agricultural research. The act increased federal funds to the states on a formula basis, similar to that of the Bankhead-Jones Act of 1935, and made provisions for support of regional research by the SAES with the federal grant funds.

It was assumed by the initial sponsors of the bill that the Secretary of Agriculture would consolidate all work on marketing, including that authorized by the new legislation, under a new agency. However, Secretary Charles F. Brannan named Mr. E. A. Meyer as Administrator of the Research and Marketing Act, with responsibility for coordinating and integrating marketing programs and policies of the department. This essentially established three main administrative units for research in the USDA, covering (a) the Reserach and Marketing Act, (b) the Agricultural Research Administration with its responsibilities for the work of the several bureaus, and (c) the Office of Experiment Stations which, while under the ARA, was involved in the new grants to the states and with the regional research conducted by the states.

The advent of the Research and Marketing Act has special significance regarding USDA and state relations, in part because the naming of a separate Administrator of the Act implied a high degree of autonomy of this work from the research under the ARA Bureaus. In any event, the planning of regional research by the states was undertaken rather independently, with a representative of a given state assigned responsibility for designing the regional project with the participation of persons from the other states in that region, but most often without invitation to the USDA national or regional program coordinator and USDA personnel working on that particular problem or commodity within that region. This led to the establishment of some duplicating regional research activities, such as for small grain improvement in the Northeastern states, for field bean research in the Western region, and several others.

In recognition of the difficulty of integrating research under the Research and Marketing Act with other existing programs of the USDA and the states, action was taken in July 1949 to give responsibility for the Research and Marketing Act to the Administrator of the Agricultural Research Administration.

One of the features of the Research and Marketing Act was the requirement that a National Agricultural Research Advisory Committee be established, with select committees on principal commodities or problem areas of research. These committees were established to include representatives of producers, processors and marketing industries, and consumers. The servicing of the committees, provision of background papers summarizing the status of problems and research on them, was a task assigned to the USDA research workers concerned with the particular subject area. This did enlist participation of many individuals with interest in research. However, the task of servicing the annual meetings of the Advisory Committees, which grew in number to twenty-three over a period of time, became burdensome and diminished the attention of USDA scientists to their research responsibilities.

The provision of funds under the Research and Marketing Act directly to the states for regional projects was a factor in lessening the close association of the USDA and the states in coordinated regional research. This reflected both the concern of many SAES research workers that there was excessive dominance and control of research by the USDA coordinating leadership, and the wish to exercise more initiative and freedom on the part of the states in the planning and conducting of regional research.

There was a substantial difference between the coordinated national or regional research projects conducted cooperatively by the USDA and the SAES and the "regional" projects undertaken by the states under the Research and Marketing Act. In the latter case, the usual procedure was to identify a problem or program area of interest to the several states in the region. The available funds then were assigned to personnel of the various states who proceeded to apply these funds for studies that "related to" the subject area. The end result was a collection of independent studies that provided information with regard to the subject, but did not interact in a cohesive and integrated manner that supplied cumulative information to resolve specific problems. This, in effect, was more of an individual project grants effort than a coordinated program to address and resolve a common problem of the area. This distinction was apparent to many of the SAES directors who, during the initial years of the Research and Marketing Act regional activities, remarked about the absence of and the need for the type of coordinating leadership and services provided by the federal personnel in the coordinated USDA/State research programs.

One evaluation of the Research and Marketing Act regional activities is furnished by the President's Science Advisory Committee, Agriculture Panel on Science and Agriculture in their report of January 1962 in which they point out (Item f. page 41) "with a few exceptions, the regional research funds have not accomplished their purpose. The administrative procedures are cumbersome. There is a tendency to 'carve up' the money allocated for each regional project among the state experiment stations. The paperwork on contributing projects, project reports, etc., has been excessive." This evaluation was made after the regional projects had been underway for about 14 years.

Despite the preceding allegation of the agricultural panel on science and agriculture of PSAC, concerted efforts were begun by the mid-1950's to incorporate federal scientists' efforts into the regional research program. Those efforts continue to the present time with most notable progress being made since the preparation of the national plan in 1966 and the subsequent developments under the Agricultural Research Policy Advisory Committee and later the Joint Council on Food and Agricultural Sciences, created under the 1977 Act.

5. Reorganization of USDA Research in 1953

The research work of the USDA was substantially strengthened, consolidated, and institutionalized during the term of Secretary James (Tama Jim) Wilson from 1897 to 1913. The scattered and rather individualized research conducted in various offices and divisions was consolidated into the research bureaus concerned with plants, soils, entomology, and other program areas. The Bureau of Animal Industry had been established prior to this time, in 1884. This structure furnished an organizational or institutional stability that prevailed for 40 years.

It is recognized that every new political administration has some compulsion to reorganize the government. (Even President Carter promised to reduce the number of government agencies from 1500 to no more than 200 as he initiated his first term in office.) The desire of new administrations to "shake-up the establishment" reflects the view that the entrenched bureaucracy maintains a carry-over of loyalty to the preceding administration and, therefore, will not be responsive to the incoming officials at the Secretary, Assistant Secretary, and immediate subordinate levels. Also, there is awareness that federal civil service employees have a permanence and continuity whereas politically appointed officials have only temporary residence in their respective offices.

Following Secretary Wilson's final term in office, there were numerous suggestions for reorganization of the Department of Agriculture, including the research function. Substantial changes were made, with some research programs and units realigned through transfers to different bureaus and agencies, and with new organizations established as emphasis was increased on soil conservation, utilization research, and other areas of concern. This reflected a continuous and consistent effort to upgrade the organization and operation of research to ensure that it evolved effectively to address the needs of a changing agriculture. Those responsible for the direction of research in the USDA, the Chiefs of the Bureaus, the Chief of the Office of Experiment Stations, and the Director of Research in the Department, usually functioned to achieve the evolutionary changes essential to keep the research relevant. But they also recognized the importance of maintaining a basic stability in the research organization and guarded against massive changes and drastic realignments coinciding with a change in political administration.

The first major restructuring of USDA research in the twentieth century occurred during the incoming Eisenhower administration of 1953. The reorganization announced by Secretary of Agriculture Ezra Taft Benson abolished the scientific Bureaus and the Office of Experiment Stations, and centralized administrative authority into the renamed Agricultural Research Service. The component units of the seven research Bureaus were set up as fifteen Branches. These were realigned, with three or four such branches reporting to Directors of Research in the Agricultural Research Service central office.

One rationale for the substantial reorganization of 1953 was to respond to the Hoover Commission Report of 1949 which was interpreted as not complimentary to the Department of Agriculture. The Commission Report recognized that the department performed many useful functions, but described the department as "a loose confederation of independent bureaus and agencies." The report recommended consolidation of all research into a research service, "divided into appropriate bureaus" (Moore, 1967).

Another factor that may have been significant in prompting the reorganization of 1953 was the difficulty faced by the administrator of the ARA and his coordinating staff in exercising strong influence in assessing or determining the levels of budgets for component bureaus in the ARA budget review process. For example, in 1952-53, as an outgrowth of the Korean War, the country was again faced with substantial agricultural commodity surpluses. The Agricultural Research Administrator was strongly supportive of substantial increases for utilization research under the Bureau of Agricultural and Industrial Chemistry (BAIC). This prompted rather vigorous discussions between the research administrator and the leadership staff of BPISAE which was requesting increased funds for a number of program areas, principally for research on cereal diseases. (It was known that race 15-B of stem rust of wheat was present in the country and strengthened research was essential to meet it. The very damaging effects of widespread epiphytotics of race 15-B occurred in 1953 and 1954.) It is probable that the rather autonomous attitudes of the Bureaus (particularly BPISAE) with regard to ARA budget planning and program coordination prompted the research administrator to centralize greater authority in the Agricultural Research Administration (Service) in 1953.

The reorganization of 1953, while presuming to respond to the Hoover Commission report, did not in fact pursue the several Commission recommendations that related to the Department. The reorganization did not continue the bureaus, and instead of the loose confederation of seven independent bureaus there emerged a total of fifteen branches in an equally "loose confederation." Also, the recommendation that all regulatory activities be consolidated into a regulatory service was not implemented. The former Bureau chiefs became directors of research for crops, farm and land management, home economics, livestock, utilization, and regulation and control.

The new organization of ARS had a deleterious effect on the lines of communication between the leadership of ARS and the directorate and department head levels in the SAES. For example, the experiment station directors were uncertain about responsibility at the federal level for fulfilling commitments relative to cooperative work with the former bureaus--whether these would now rest with the office of the ARS administrator, the directors, or the branch chiefs.

There was less disruption in the cooperative relations at the field level, as noted by Dr. Howell in discussing the national soybean research program earlier in this report. He pointed out that, although he had been with the cooperative program for only one year, he noticed no significant effect on the federal-state relations. This reflected in part the fact that Dr. Martin G. Weiss, who had become investigations leader for the national soybean program in 1949 subsequently was named head of the Forage Crops Division and then, in the reorganization of 1953, he became the Branch Chief for Field Crops. This provided a special degree of continuity of line responsibility for this national program. In general, the disruptions of line/staff roles were perhaps of major concern in the Beltsville/Washington scene, and at the equivalent levels in the SAES, with minor repercussions at the field or working scientist level.

The operation of the new structure within ARS proved to be less than satisfactory as evidenced by the fact that after four years, in 1957, the branches were again realigned, the "division" positions were abolished, and "deputy administrators" were named for farm research, home economics research, marketing research, and utilization research. Similarly, after several years it became apparent that the combining of the administrative services from the former research bureaus into a centralized operation in ARS was not satisfactory and so the ARS administrative services, including the fiscal and personnel work, were decentralized into four regional offices, in Philadelphia, Minneapolis, New Orleans, and Berkeley. In theory, this placed such services closer geographically to the ARS staff in the field. In fact, the effect was to detach these services from the research bureaus and/or branches--where they had sufficient contact to become familiar with programs and staff--and place the "services" in area offices where they could not maintain familiarity with the activities they were to serve, and where they had no special sense of obligation to respond to the needs of the scientific staff.

The reorganization of 1953 abolished the Office of Experiment Stations, which was of serious concern to the SAES directors. Originally, following passage of the Hatch Act in 1887, the Office of Experiment Stations reported directly to the Secretary of Agriculture. This continued with the Office of Experiment Stations on the same level as the research bureaus until the Agricultural Research Administration was established in 1941. After this time, its Chief reported to the Administrator of the Agricultural Research Administration rather than to an Assistant Secretary of Agriculture.

When the ARS was formed in 1953, the work of the Office of Experiment Stations was taken over by two new ARS divisions: (a) the State Experiment Station Division, and (b) the Territorial Experiment Station Division. This issue remained a discordant factor in USDA-SAES relationships until 1961, when a new independent agency, the Cooperative State Experiment Station Service, was created, with an administrator reporting directly to the Secretary of Agriculture or an Assistant Secretary. (The name of this unit was later changed to Cooperative State Research Service.)

The reorganization of 1953 not only had a disrupting influence on the operation of the USDA, and on the USDA-SAES relations through the balance of that decade, but a continuing deleterious effect on the stature and respect for agricultural research in succeeding years. This was particularly obvious in the attitude of the President's Science Advisor's Office, especially Dr. James B. Hartgering, who expressed the view that research in government was generally poor and that research in the USDA was essentially the poorest of the poor. It was reflected also in the views of some experiment station directors, in part channelled through Assistant Secretary Frank Welch (former Dean of Agriculture at the University of Kentucky) with respect to the suggested antagonism of research administrator Byron T. Shaw toward the state agricultural experiment stations. These attitudes, in 1963, were a decade after the reorganization of 1953.

The relationships between the leadership of USDA research and the Congressional Committees also were affected by the reorganization of 1953. Dr. Earl Glover refers to the attitude of Congressman Whitten who stated that he missed the presence and discussions of the former bureau chiefs because they were familiar with the research and "knew what was going on." Congressman Whitten expressed the same view to the senior author of this paper, who was serving as Science Advisor to Secretary Freeman during March through April 1963, at a luncheon meeting on May 2, 1963, to the effect that "Dr. ____________________ (a witness for support of ARS budgets) is obviously nervous when he appears before the House Committee (chaired by Congressman Whitten) because 'he does not have an in-depth understanding of the programs he is supporting, he knows it, and he knows we know it.' Our committee gives him a hard time for a short while but then we ease up on him because we realize that in his position he is no longer in direct contact with the research he must defend." This attitude of Congressman Whitten, a decade after the 1953 reorganization, was exacerbated following the further reorganization of 1972 when some national program staff members were even less familiar with the research they were expected to describe and defend before congressional committees. This is reflected in the hearings before the Subcommittee on Agriculture, of the House Committee on Appropriations, on Environmental and Consumer Protection Appropriations for 1975.

6. Collaboration of the USDA with Private Industry

The rapid "chemicalization" of agriculture during World War II caused fertilizers, pesticides, and herbicides to be regarded as essential inputs in American agriculture in all farming regions of the country. The USDA and SAES research adjusted to meet the needs for more precise information for effective and efficient use of these materials.

The evolution of herbicides--with highly selective chemicals capable of killing specific weeds in various crop plants--progressed rapidly after World War II, with many chemical companies producing a variety of materials that moved into the market place. In order to provide for an orderly and systematic assessment of the efficacy and general suitability of such new materials a Weed Research Division was set up in BPISAE in 1951. This was an outgrowth of the first coordinated USDA-SAES coordinated weed research program, the cooperative work in the Midwestern states to control field bindweed, set up in 1936. Dr. R. L. Lovvorn of the North Carolina Agricultural Experiment Station was named head of the Weed Research Division and wide-ranging programs were established that involved cooperation with the Army Corps of Engineers to eradicate the water hyacinth from inland waterways and canals in the Southern states, continued cooperation with the SAES for control of field bindweed and other noxious weeds, the control of halogeton--the poisonous weed of Western rangelands--and the control of mesquite and other brushy shrubs and plants in the Southern Great Plains states. The program involved not only the basic pattern of USDA-SAES cooperation in which federal scientists were located in cooperating state stations and state research workers participated actively in coordinated programs, but also a strong centralized laboratory and field effort at the Beltsville headquarters where intensive studies were undertaken to carry out preliminary evaluation of the large flow of new chemicals appearing on the scene from chemical industries. In addition, basic studies were conducted to determine the physiological processes involved in action of the selective chemicals.

Scientists of the various chemical companies concerned with herbicides participated as full team members in the research, including involvement in extensive field tours to observe the performance and effectiveness of weed and brush killers in various areas of the United States.

There was continuing concern about the potential hazards to health--to humans and animals--of the new chemicals, particularly the potent insecticides and the herbicides. The BPISAE initiated studies on the effect of DDT on plants and soils, including its persistence in soils, in the 1940's before the end of World War II. Effects on animals were determined by the Bureau of Entomology and Plant Quarantine, particularly at the laboratory in Kerrville, Texas.

In order to ensure attention to this problem, the Director of Crops Research, the Assistant Director (Dr. H. L. Haller, who was involved in the early research with DDT and other insecticides as well as in the development of the aerosol propellant), the Chiefs of the Field Crops and Entomology Research Branches, and the leader of Weed Investigations, visited the counterpart researchers in a number of the chemical companies, including Hercules, DuPont, American Cyanamid, Dow Chemical, and others in 1954-1955 to develop arrangements for the joint testing of new agricultural chemicals. The USDA offered to test not only the effectiveness and suitability of new chemicals but also the effects on animals at the Kerrville and other laboratories. Some industry personnel were concerned about patent rights, fearing that the USDA would claim public service patents for the new chemicals. However, they were assured that company rights would be respected and that the purpose of the federal participation was to ensure greater attention to the effectiveness of the chemicals and to potential health hazards.

Some questions were raised with respect to the propriety of a tax-supported organization such as the USDA cooperating with private organizations working for profit. The response of USDA personnel was that such cooperative research was definitely in the public interest, not only to ensure that farmers were supplied with materials that were effective and efficient but also that the public would receive maximum protection against any possible harmful effects from these materials.

During this time, 1954-1955, additional appropriations were requested through the Crops Research Division for the strengthening of research on (a) insect physiology to help better understand the mechanism of action of insecticides, (b) instrumentation to improve detection of minute quantities of chemically active substances, and (c) the composition of effluents of various manufacturing plants and the effect of such materials on surrounding crops and animals. It should be noted that this interest and initiative was taken by the USDA in the early 1950's, a decade before the book Silent Spring by Rachel Carson, in 1962, was published, creating the widespread notion that USDA scientists lacked a social conscience and were derelict in exercising due care and responsibility in research on pesticides. This subject will be discussed more fully in Chapter III.

The USDA research in fertilizers was also undergoing change in the early 1950's. A new laboratory established at the Plant Industry Station at Beltsville in 1950, in cooperation with the Atomic Energy Commission, provided for studies with radioactive phosphorous and other elements in plant nutrition. Also, at this time, action was taken to modify fertilizer investigations, with basic studies continued at Beltsville and pilot plant investigations undertaken in cooperation with the Tennessee Valley Authority and various private companies.

The fifteen years from 1945 to 1960 were marked by continuing adjustments and adaptations of organization and operations to strengthen research by the USDA and the states to keep pace with and guide the rapidly modernizing US agriculture. This period also was marked with the very drastic reorganization of 1953 with its repercussions on the functions and capabilities of USDA research, the uncertainties and dissatisfactions with respect to administration of federal grant funds to the states, and disruption of the cooperative federal/state relationships. This action also had continuing reverberations into future decades.

B. SAES

1. Changes in Emphasis and Stature of the Land Grant Institutions

The period from 1945 to beyond 1960 was a time of very rapid growth in the size and scope of university programs, particularly areas other than agriculture and the mechanical arts. The immediate post-World War II period accommodated to the large influx of students on a catch-up schedule, many in the applied sciences, so it was really the decades of the fifties and sixties that saw major changes in character of the Land Grant institutions. Large increases of students in colleges of education and in the basic sciences were experienced, and funding for proliferation of programs was plentiful. It was during this "golden age" that many colleges achieved university status, and both undergraduate and graduate programs flourished.

During this period, the interest in the basic Land Grant programs in agriculture and mechanic arts dwindled. The more glamorous programs in the sciences, and the opportunities in primary and secondary education, with the rapid growth in students there clearly had the limelight. It was not until the post-Sputnik era that engineering came back to the fore, and through the late 1960's and most of the 1970's that interest in agriculture was rekindled.

2. Rapid Expansion of Facilities and Budgets for Agricultural Research

Fortuitously, throughout the same period that agricultural enrollments in the universities were languishing, interest in agricultural research was booming in response to the rapid industrialization and the search for new technologies in agriculture. Technology was the watchword, and both federal and state governments responded with regularity in increasing budgets to generate that technology. It is of more than passing interest to note that the beginning and the end of the growth cycle in research funding coincided with the ending and the new beginning of growth cycles in student populations in agriculture in the universities. These trends are clear during the periods 1950 to 1965, and 1966 to 1976. The recent modest declines in agricultural enrollments have not, however, been accompanied by a return of the growth trend in the funding of agricultural research.

3. The Research and Marketing Act of 1946

In terms of impact on the organization, management, and character of state agricultural experiment station research and the relations between USDA and the state stations, the Research and Marketing Act of 1946 contained another landmark provision. That act formalized the authorization for the states to engage in research on an interstate cooperative basis and established the regional research fund as a separate element of the federal appropriation--an element to be managed by the department through a cooperative planning process with the state stations. The existence of the regional research program has perhaps done more to enhance the cooperative research planning and implementation processes by the SAES than any other single action. It built onto the philosophic notion that cooperative activities were good, a funding arrangement that served as the carrot to cause it to happen. The state stations now had a very tangible reason to work together among themselves and to cooperate in additional ways with USDA in an institutional as well as individual scientist framework. However, as discussed previously, the cooperation between the states that was fostered by the Research and Marketing Act coincided with a lessening of the long-established cooperation of the states and USDA Bureaus in many coordinated programs which extended throughout the 1950's and much of the 1960's. Reversal of that trend began with the development of the 1966 Long Range Plan and has continued since under the cooperative model established by the Agricultural Research Policy Advisory Committee and more recently the Joint Council on Food and Agricultural Sciences.

4. Project Grant Support Through Federal Agencies Other Than the USDA

Beginning in the 1950's, there began also large infusions of funding to research in other federal agencies, in particular the National Science Foundation, the National Institutes of Health, and the National Aeronautics and Space Administration. Such funding was not institutionally oriented, but rather was supportive of specific grant proposals from both individuals and groups of scientists. The availability of such resources in large amounts impacted the state agricultural experiment stations and the land grant colleges and universities in a variety of ways. First, it provided individuals and groups of scientists an avenue to solicit and conduct research using those grant resources. Thus, individual scientists no longer had to look exclusively to the administrators of the colleges and stations for support, but rather could go where the money was. And many did. By moving to these kinds of funds, the granting agencies rather than the station managers began to exert significant control over the activities of scientists within the station, and thus the nature of the stations' program itself.

At the same time, agricultural business and industry was beginning to invest more heavily in research--in particular, the chemical industry--in development, evaluation, and testing of pesticide chemicals and fertilizers. This industry grant support changed the nature of research programs in another direction; namely, away from basic, and into applied or evaluative research.

Thus, there grew a divisive set of perspectives within the stations' programs, one dimension moving to heavy federal support of basic research, and another element moving to applied research and development.

In addition to the outside influences on programs, the stations themselves behaved differently in response to availability of these resources. Some strongly promoted the capturing of grant funds to enhance programs, even if this did change the direction of the programs in a significant way. Others were more conservative and tended to accept only those grant funds that supported the plans and activities of the station and its individual scientists.

In any case, the impacts on the stations were many and varied, and even spun off to impact on the instructional programs of the Land Grant colleges and universities. The grant funds generally tended to finance more graduate students in both basic and applied research, and served to shift the attention of many college and university faculty members away from the classroom and into the research laboratory. Also, with grant funds for basic research from agencies outside of agriculture there was deep concern among many state and federal scientists and administrators that the attention and interests of top level agricultural research workers were diverted from agricultural problems. This resulted in increasing pressures in the early 1960's for project grant funds to be provided by the federal government for agricultural research.

III. THE ERA OF RAPID CHANGE, 1960-1980

A. General Considerations

The past twenty years, from 1960-1980, have been marked by much volatility concerning the prestige and support for research. This is a general phenomenon and not restricted to agriculture. These two decades have seen the special impact of social forces on research priorities, and numerous assessments of research that have had a cumulative effect on reshaping the national agricultural research system and capabilities. The review of some of these factors would seem essential to providing an understanding of where we are, why and how we got there, and what modifications should be made in the system to improve it.

The earlier historical resume of the evolution and shaping of the national research capabilities helps to furnish an understanding of the forces, judgments, and responses of agricultural research leaders--particularly through the decades from 1930-1960--when American agriculture was developing as the most productive in the world. The assessment of the various factors influencing the national agricultural research system in the past twenty years should be a deeply analytical and critical evaluation to determine the various impacts on the national research capability--to furnish a base for recommendations for improving the system.

B. Reviews and Reorganizations of USDA Research

1. The President's Science Advisory Committee, Agriculture Panel on Science and Agriculture

As stated before, new national political administrations approach their leadership tasks with a basic conviction that the existing federal bureaucracy has a residual loyalty to the previous administration. Therefore, government organizations are assumed not to respond promptly to the direction of new incoming political leadership. The Eisenhower/Benson administration succeeded in bringing about the drastic and far-reaching reorganization of USDA research in 1953. This had the effect of subjecting the research structure of the Department--which had substantial stability and immunity from political interference for forty years, since the days of Secretary James Wilson in 1913--to a succession of pressures for further drastic reorganizations with the changes in political administrations in future years.

A cumulative effect of the unsettled situation in USDA research in the 1950's, and somewhat similar performances in the research of other federal departments and agencies, caused the President's Science Advisory Committee (PSAC), and the Science Advisor to President Kennedy, Dr. Jerome B. Weisner, to concentrate special attention on the capability and quality of research in the federal government.

The Life Sciences Panel of the President's Science Advisory Committee arranged for a review of Science and Agriculture, focused primarily on the USDA. The Panel, chaired by Dr. J. George Harrar, President of the Rockefeller Foundation, had James B. Hartgering, MD, Office of the Special Assistant for Science and Technology, as the technical assistant, and included seven professors of American universities as members. The panel had two consultants, one from the University of Minnesota and another from the Farm Research Service of the USDA.

The membership of the Agricultural Panel was as follows:

J. GEORGE HARRAR, Chairman	Rockefeller Foundation
ALFRED M. BOYCE	University of California
RICHARD BRADFIELD	Cornell University
GEORGE A. GARRATT	Yale University
JAMES G. HORSFALL	Connecticut Agricultural Experiment Station
W. M. MYERS	University of Minnesota
GLENN W. SALISBURY	University of Illinois
THEODORE W. SCHULTZ	University of Chicago

Consultants:

WM. G. KUBICEK	University of Minnesota
THEODORE BYERLY	Farm Research Service, Department of Agriculture

Technical Assistant:

JAMES B. HARTGERING, M.D.	Office of the Special Assistant for Science and Technology, The White House

The Panel recommendations, in their report of January 1962, included the following which are relevant to the present OTA study:

a. An Assistant Secretary for Science and Technology should be appointed in the USDA to devote full attention to the Department's activities in both domestic and foreign science and technology.

b. A Committee on Agricultural Science should be appointed to advise the Assistant Secretary for Science and Technology. This committee should be composed of scientists representing the disciplines important to agricultural research.

c. The present commodity-oriented agricultural structure of the Agricultural Research Service should be modified toward a scientific discipline structure (similar to the organization in universities).

d. Many of the USDA field research stations should be closed, or transferred to the SAES for operation, and existing or new research facilities should be associated with a university.

e. Research functions of the USDA should be separated from control and action programs (with specific mention of meat inspection and plant quarantine).

f. The Assistant Secretary for Science and Technology should study methods of improving the organization and administration of regional research. The panel pointed out that "with a few exceptions, the regional research funds have not accomplished their purpose. The administrative procedures are cumbersome. There is a tendency to 'carve up' the money allocated for each regional project among the state experiment stations. The paperwork on contributing projects, project reports, etc., has been excessive."

g. The Assistant Secretary for Science and Technology should study the interrelationships and foster integration of USDA research with other government agencies concerned with common areas of scientific interest such as water pollution, chemical residues in plants, contamination of the food chain with radionuclides, and hazards of radiation.

h. A significant part of the resources of the US agricultural scientific community should be utilized to support national foreign policy.

i. The Agricultural Research Center at Beltsville should be developed into a recognized national and international center of basic science--with more great minds and better research support to enable Beltsville to achieve the status of a world renowned research center.

j. The library of the Department should be developed into a national facility.

k. A new grant program, designed for the individual research worker for support of specific research, should be initiated by the USDA. The report pointed out that "the individual scientist interested in basic research has no such source of support from the Department. He must turn to other agencies such as the National Institutes of Health, the National Science Foundation, and the Atomic Energy Commission." The panel expressed concern that too large a number of agricultural scientists would turn their talents to other fields of interest unless such grant funds were available through the USDA.

l. Opportunities for scientific growth and achievement of agricultural scientists should be improved through sabbatical study, better facilities and equipment, and less specific direction by their administrators as to objectives and procedures of research.

m. Basic research in sciences related to agriculture should be substantially expanded relative to applied research.

n. Utilization research should be the subject of a special study. The panel pointed out that "utilization research has been expected by many to provide a solution to the surplus problem. In the view of the panel, this is wishful thinking." The panel emphasized greater attention to the balance between support for utilization research and that for farm and marketing research.

o. The panel recommended that fundamental research on the problems of agricultural adjustment be intensified, with more basic information on the economic and sociological factors involved in such adjustments.

The foregoing recommendations of the Agriculture Panel of PSAC were generally constructive and positive. However, the review was conducted within an environment that was generally critical and hostile toward the USDA. For example, Secretary Freeman stated in April 1963 that he had been cautioned that "the Administrator of the ARS was strongly loyal to the 'Benson administration' and was not sympathetic to the state experiment stations or to USDA cooperation with the states." Secretary Freeman subsequently stated that as he became acquainted with the Administrator he found him responsive, generally furnishing good leadership to the research of the Department, and positive in support of cooperative work with the states.

A Committee on Agricultural Science was appointed by Secretary Freeman on April 16, 1962, following a conference with Dr. Weisner, Chairman of PSAC.

The membership of the Committee was as follows:

W. M. MYERS, Chairman	University of Minnesota
A. G. NORMAN	University of Michigan
W. C. BRAMBLE	Purdue University
J. K. LOOSLI	Cornell University
W. G. KUBICEK	University of Minnesota
EDWARD A. STEINHAUS	University of California
W. T. S. THORP	University of Minnesota
ROY BAINER	University of California
M. B. RUSSELL	University of Illinois
M. E. JOHN	Pennsylvania State University
R. G. BRESSLER	University of California
R. L. CLODIUS	University of Wisconsin
C. E. BISHOP	N.C. State College
M. M. KELSO	University of Arizona
MELVIN CALVIN	University of California
E. C. ELTING, Exec. Sec.	USDA, ARS

The fifteen member Committee included 4 from the University of California and 3 from the University of Minnesota. Five of the fifteen were economists or social scientists. E. C. Elting of the Cooperative State Research Service served as executive secretary but there was no representative of the ARS with experience in coordinated national or regional programs cooperative between the USDA and the states. Also, there was no representative from other federal research agencies with an understanding of national research responsibilities, relations with the Bureau of the Budget and with House and Senate committees, and interactions in research with other departments and agencies of government. The dominant university representation on the Committee on Agricultural Science and the Agriculture Panel of the President's Science Advisory Committee, and the attitude of staff members of the White House Office of Science and Technology combined to reflect the low esteem of research in the USDA and also the viewpoint that university personnel should have a dominant role in the planning and direction of USDA research.

There was substantial ferment in the federal government in 1963 with respect to research. The Rules Committee of the House of Representatives, under the chairmanship of

Representative Howard Smith of Virginia, initiated an investigation to assess the more than $14 billion per year spent for research and development, primarily by the Defense Department, National Aeronautics and Space Administration, National Institutes of Health, U.S. Information Agency, and the Disarmament Agency. These agencies were accused of "wasting millions of dollars on useless research."

Science advisors/consultants were appointed in a number of Departments, to work at the Secretary level to assist in assessing and strengthening research capabilities. Dr. Roger Revelle was designated in this capacity in the Department of the Interior and Dr. Herbert Holloman in the Department of Commerce. Dr. A. H. Moseman was the Consultant for Research in the USDA, followed by Dr. Nyle C. Brady. The basic assumption of the Office of Science and Technology in taking the initiative in establishing these positions was that federal research capabilities were inadequate, stagnated, and lacking in imaginative leadership.

A number of significant steps were taken during the first six months of 1963, with the active involvement and full support of Secretary Freeman, including the following:

a. Research facilities. The PSAC Agriculture Panel evidently was not aware of initiatives taken by the ARS to transfer certain federal field stations to the states in which they are located. P.L. 835 of the 81st Congress, approved on September 23, 1950, provided for closing or transfer of the USDA stations at Huntley, Montana; Mitchell, Nebraska; Fallon, Nevada; Tucumcari, New Mexico; Hermiston, Oregon; and Sheridan, Wyoming. From January 1, 1958, to September 1, 1962, USDA research was closed out by the ARS at 33 field locations.

   A problem in establishing USDA facilities on land grant university campuses was exemplified at the time by the request from Michigan State University to remove or transfer the Bankhead-Jones Poultry Research Laboratory from the MSU campus to make room for additional dormitory construction, and the request from Colorado State University to remove temporary structures on the campus at Fort Collins in which federal scientists were housed in order to permit construction of new university buildings.

   During this time there was a spate of construction of new laboratories and field stations, for soil and water research, utilization research, the livestock research station at Clay Center, Nebraska, and other facilities developed on the initiative of USDA personnel, state experiment station staff, or by members of Congress. In order to minimize the precipitous and haphazard construction of research facilities, and to improve the understandings of the USDA and the state experiment stations with respect to priority facility requirements, a joint USDA-SAES review team was established by the Secretary to consider research facility needs over the coming five-year period and develop a priority listing of such construction. A representative was selected from each of the four agricultural experiment station regions and an equal number represented the USDA agencies. The initial meeting of this committee was held on June 27-28, followed by another meeting in September 1963. It was felt that joint attention to research facilities would be one means of strengthening linkages between the USDA and SAES.

b. Advisory committees. The Research and Marketing Act of 1946 provided for establishment of a National Agricultural Research Advisory Committee. The NARAC, by the law, required eleven members, six of whom would be representatives of producers or their organizations, and would meet quarterly. In addition, through the years since 1947, 23 commodity and functional research and marketing advisory committees had been established under the provisions of the Act. The Committee on Agricultural Science, established by Secretary Freeman in April 1962, included 15 members who met every other month. In addition, selected subcommittees of the CAS were holding meetings lasting from one to three days.

   Although there was full appreciation of the importance of having outside reviews of USDA research, the combined committees required about 2,000 days of travel, considerable time on the part of those who were members of the committees and, more importantly, a substantial drain on the time of USDA scientists who were required to prepare comprehensive background papers describing research of the Department and identifying additional research needs. There was concern on the part of the Secretary, and Congressman Whitten, that elimination of any of the 23 committees would be interpreted as a desire by the Secretary to reduce and minimize outside participation in the review and guidance in planning of research. Secretary's Memorandum 1544 of August 26, 1963, stated that the 23 RMA advisory committees were being realigned into 11 committees, and invited public participation by persons who were not designated as formal committee members.

The issue of administration by and through committees is a continuing one. In this connection it should be noted that the PSAC Agriculture Panel Report of January 1962 (page 9), and the USDA Misc. Pub. No. 904, State Agricultural Experiment Stations, May 1962 (pages 195-205), express concern about the cumbersome and costly procedures involved in the planning and conduct of research via the Committee of Nine, the Regional Research Committees, and other administrative measures that emerged from the Research and Marketing Act of 1946. This is discussed more fully later in this paper.

c. Separation of research and control or regulatory programs. The Agriculture Panel of PSAC recommended that control and regulatory functions be eliminated from ARS since funds for such programs were substantial and tended to leave the impression that larger budgets were being expended on research than was actually the case. In assessing this situation, it was recognized that it would not be desirable to separate pest control and plant quarantine and regulatory activities from ARS research at a time when there was growing concern over the use of pesticide chemicals. On the other hand, it was recognized that it would not be essential to retain the routinized functions such as meat and poultry inspection in association with research. There were, however, strong reservations on the part of the poultry industry, for which the inspection program was under the Agricultural Marketing Service, to being associated with the red meat inspection service, which was handled under the ARS. Although discussions and actions were initiated to combine these programs in the first half of 1963, the actual merger of poultry inspection and meat inspection was not brought about until July 1968.

d. Pesticide use and research. The record of research--and research program planning and budget recommendations--of the USDA and of many of the state experiment stations indicates the interest and concern about agricultural chemicals, particularly insecticides, fungicides, herbicides, and other plant growth regulators from the early 1940's when these materials came into increasing widespread use. ARS entomologists and chemists shared the concern of toxicologists about possible harmful residues of new chemicals (Moore, 1967). In the hearings of the House Appropriations Subcommittee for fiscal 1951, held January 23, 1950, for example, there are five pages of discussion of the need for more information on the potentially harmful effects of insecticides. A request of $93,000 was made to expand such research. Similar requests for more research on biological control of insects, on improved instrumentation, on insect physiology, as well as on effects of residues on soils, plants, and animals were presented each year by the research staff of the ARS. Such requests were consistently reduced by the administration and the Congress. The publication of the book Silent Spring by Rachel Carson in 1962 carried the accusation that pesticide chemicals were released rather indiscriminately, with little or no investigation of their effects on soil, water, wildlife, and man, and fostered a general indictment by the media of scientists and others concerned with the development and usage of pesticides.

The Department of Defense, the Public Health Service, the Fish and Wildlife Service, and the Food and Drug Administration, as well as some other agencies of government, were in the picture but the primary focus was on the ARS. President Kennedy requested his Science Advisory Committee to study the subject and after exhaustive hearings the committee report "Use of Pesticides" was released on May 15, 1963, with a forward by the President advising that he had already requested the responsible agencies to implement the committee recommendations. On the day following the release of the report, on May 16, 1963, hearings were initiated by a committee presided over by Senator Abraham A. Ribicoff of Connecticut, commonly referred to as the "Pesticide Hearings," which continued intermittently for about 15 months.

One effect of the public arousal of Silent Spring was the increase in funds for research on pesticides from a requested increase of $500,000 in 1964 to an increase of about $30 million in fiscal year 1965. Much of this fund was to be used for construction of new laboratory facilities.

In the summer of 1964, as the Ribicoff Committee hearings were nearing their end, the Agricultural Subcommittee of the House Appropriations Committee directed its staff to conduct an investigation on certain aspects of pesticides. This was based on the feeling that the farmers of the country, the USDA, and the agricultural colleges and universities had been subjected to unfair and unsubstantiated criticisms in the pesticides debate. A principal purpose was to allay some of the fears and apprehensions caused by Silent Spring and the media treatment of the subject. The staff report stated, "The staff was advised by scientists and physicians that the book is superficially scientific in that it marshalls a number of accepted scientific facts. However, it is unscientific in (a) drawing incorrect conclusions from unrelated facts, and (b) making implications that are based on possibilities as yet unproved to be actual facts."

The book Silent Spring was the forerunner of many similar publications that extrapolated broadly from limited information and indulged in assumptions and speculations that frequently caused public concerns and fears about health and environmental hazards that in many instances proved unwarranted. Silent Spring served a useful purpose in creating public awareness of the potential hazards from the irresponsible application and use of agricultural chemicals. At the same time, it created a basic distrust of scientists in the USDA, in private industry, and in state agricultural experiment stations--leaving the implication that such scientists lacked a social conscience and were concerned only with winning wars against pests and increasing agricultural production. The extensive hearings, by the Ribicoff Committee, and subsequently by the House Appropriations Committee Task Force, inflicted a high cost in taxpayer dollars.

e. Project grants. The increasing pressure for a program of research grants to individual scientists, to be administered through the USDA, came at a time when the Congress was becoming deeply concerned about the use of funds for such grants by the Department of Defense, the NASA, AEC, NIH, NSF, and other organizations. There was general agreement within the Department, the Bureau of the Budget, and Congressional committees that project grant funds should be provided. However, there was a difference of opinion as to the channels for such grants. One group felt that the best procedure for requesting grant funds would be through association of such funds with the regular ARS Division requests, to permit identification of the overall field of research involved and furnish some assurance to the Congressional Appropriations Committees that research under the grants would be coordinated with or related to other public funded research for the same general purposes. In opposition to this was the view that such action would tend to circumscribe the scope of subject areas and also would place the ARS in a dominant position in administering the funds. The alternate proposal, to have the funds granted through the CSRS, was eventually implemented.

f. Facilities at Beltsville. The PSAC Agriculture Panel, in its report of January 29, 1962, recommended that the Agricultural Research Center at Beltsville be developed into a recognized national and international center of basic science. This recommendation (1) recognized the importance of having an internationally respected center of excellence for US agricultural research, and (2) emphasized that the work of this center be focused on basic research. In the latter instance the Panel was not fully aware of the important role the Beltsville headquarters staff played in conceptual leadership in continually assessing geographic potentials and requirements for agricultural research and development thoughout the United States, and the role the staff at Beltsville played in coordinating and servicing the many national and regional research programs cooperative with the state experiment stations.

The latter point was emphasized by a scientist who had come to Beltsville in about 1950 from an agricultural experiment station, and served at Beltsville for about 15 years before assuming the leadership of a cooperative regional laboratory located on a land grant university campus. Following his retirement, he commented about his years at the Beltsville Research Center, stating, "That was an exciting and challenging period--knowing that no matter where you stood on the Research Center campus you need not walk more than one half mile to find a person who knew perhaps more about the problems and conditions of agriculture within his scientific field than any person in the United States." This in no way implied lack of appreciation for the many competent scientists in the states but recognized the assembled multidisciplinary capability that could not only respond promptly to the many inquiries by members of Congress, government officials, agricultural organizations and trade associations, but also could serve effectively in representing the interests of growers, consumers, and of research scientists in addressing problems of national, regional, and local concern. This capability for coordinating and servicing national and regional programs has been diminished and weakened substantially in the past decade.

There has been a continuing negative attitude on the part of the Congress and others toward the construction of additional facilities at Beltsville, recognizing that the building of research laboratories in the states is more palatable politically. In reviewing the situation in 1963, it was recognized that aside from the Atomic Energy Commission supported laboratory for research in soils and plant nutrition, a poultry laboratory, and one or two other minor additions there had been no major construction at Beltsville since the relocation of the research facilities from Arlington Farm (to permit construction of the Pentagon) in the early 1940's. It was recognized that it would be highly desirable for the USDA to move ahead vigorously with developing new research facilities at Beltsville related to (1) pesticides, (2) animal parasites, and (3) human nutrition and food quality. Also, it was urged that the Department library be located at Beltsville in order to serve effectively as a national library resource that would interact with the National Medical Library in Bethesda and the Library of Congress. There were the usual competitions for location of the various facilities in different regions of the U.S., including a proposal to locate the library at the National Agricultural Hall of Fame in Kansas City, some of the pesticides research facilities in the Research Triangle in North Carolina, etc.

The need for building a national research center for agriculture, in keeping with the international image of excellence in agricultural research in the U.S.--as recommended by the PSAC Panel of 1962--is as pressing in 1980 as it was in the early 1960's. This does not mean large capital developments although laboratories that would consolidate scattered complementary investigations should be considered. More important is the need to restore the level of conceptual and coordinating leadership based on in-depth understanding of nationwide agricultural potentials and research programs and requirements.

g. Support for basic research. There has been a continuing clamor for additional emphasis on basic research since the early 1950's, when the commodity surpluses that accumulated following World War II and again following the Korean War caused deemphasis of production oriented reseach. In the early 1950's there was a drive to redirect up to 50 percent of the USDA resources to basic research projects. This received further emphasis in the late 1950's when the launching of Sputnik by the Russians caused concern that the US was falling behind in basic research. The outpouring of federal funds as grants to individual projects from the NSF, NIH, NASA, AEC, and other agencies came in massive amounts--leading to the concerns of Congress by 1963 that such basic research funds were wasteful and poorly administered.

The ARS established a number of "pioneering laboratories" at Beltsville and in the Regional Laboratories in the 1950's and there evolved a concept that Beltsville should be increasingly concerned with basic research, reflected in the recommendation of the PSAC Agriculture Panel of 1962 and the subsequent reorganizaton in 1972.

In the assessment of the importance of and need for basic research with Secretary Freeman during the early part of 1963 the senior author pointed out that while basic research is important, much of the new understanding of phenomena comes from scientists with the initiative and imagination to pursue facets of problems that arise in the course of their practical and applied research endeavors. Also, at that time it was pointed out that the Act creating the Department of Agriculture in 1862 defined as one of its purposes "to acquire and diffuse among the people of the United States useful information on subjects connected with agriculture, in the most general and comprehensive sense of that word," which suggested that it would be reasonable for the Department research program to continue a strong focus on mission oriented or problem solving research. This is a posture still recommended by many persons concerned with US agriculture, and particularly by those who are concerned that the federal grant funds are increasingly regarded as "soft federal monies" that do not require the same accountability and integrity of use as the core research budgets of the USDA and the SAES.

h. Federal grants to the states. It is worthy of note that the discontent of the SAES that resulted from the abolishing of the Office of Experiment Stations in the reorganization of 1953, substituting an Assistant Administrator for Experiment Stations, with a State Experiment Station Division and a Territorial Experiment Station Division, continued for essentially a decade. This was resolved in part when a Cooperative State Research Service was established in 1961 with an administrator who reported to the Director for Science and Education, at essentially the same level as the Administrator for the Agricultural Research Service. However, there was some continuing concern because the CSRS Administrator was a former USDA scientist.

The difficulty in determining program responsibilities and budgetary support for the ARS and the CSRS continued. The downgrading of the cooperative national and regional commodity research programs, for which the ARS furnished a significant participating as well as a coordinating-servicing role, was a key factor contributing to this blurred image. With the relaxation of pressure on agricultural research for the solution of critical production problems, and a rather general public apathy toward further advance in agricultural science and technology resulting from the agricultural surplus situation, there was a definite loss of the cohesive forces that once existed in USDA-SAES cooperation.

The joint ARS-State Experiment Station Committee on Research Facilities, established by Secretary Freeman in June 1963, was one move to restore cooperative joint attention to a priority problem of mutual concern. The Committee on Agricultural Science, although badly imbalanced by lack of USDA or federal research scientists, permitted an involvement by the states in national agricultural research planning and assessments. During the time that Dr. Nyle C. Brady served as Director for Science and Education in the USDA, in the 18 months beginning in October 1963, a number of steps were taken to strengthen USDA-SAES research. Among these was the comprehensive study that resulted in the report, "Long-Range Plan of Agricultural Research," published in 1966.

The concern about the lack of focus and orientation of research was not limited to USDA scientists. Directors of the SAES also faced increasing difficulties in keeping abreast of activities of their staff members as individuals received project grants, involved colleagues from their departments or other disciplines in the project, and became less responsive to the Department and Station leadership. The concept of the various federal grants as "soft monies" carried with it--in the eyes of many grant recipients--the concept that there should also be limited direction and accountability for such monies.

Senior personnel in the SAES and the Land Grant Universities retained an appreciation of the importance of USDA-SAES cooperation, as reflected in the statement of President Elmer Ellis of the University of Missouri in his address to the International Rural Development Conference, sponsored by the U.S. Agency for International Development, in Washington, D. C., on July 27, 1964. President Ellis said:

> "I have the honor of being president of the Association of State Universities and Land-Grant Colleges. I have often reflected upon the curious local, state and national orientation of these colleges and universities. They are in every sense state schools which are woven into the warp and woof of each state's culture. Yet nearly all of them came into being because of an act passed by the National

Congress. Moreover, many of the Land-Grant schools would never have survived those tumultuous early years without the support of that national land grant. State appropriations for state universities operations did not begin until the 1870's. Federal monies have always been a major part of the budgets of these state institutions. There are many good reasons for this federal-state partnership which has evolved. The benefits of agricultural research very seldom stop at the state boundary. There is no such thing as a Missouri vaccine for hog cholera."

There was no major disruption or reorganization of USDA research in the 1960's although there were the continuing adjustments--in advisory committees, inspection and regulatory activities, and consumer-related research and services, and increasing concerns about conservation and the environment. Secretary Freeman worked closely with the Director for Research and Education, the ARS and CSRS Administrators, and the Committee on Agricultural Science to strengthen the national agricultural research system in 1960-1968.

2. Creation of the Agricultural Research Policy Advisory Committee

One of the direct outcomes of the joint planning that went into the research facilities study initiated by Secretary Freeman and the later report, "Long Range Plan for Agricultural Research" of October, 1966, was the signing of a memorandum of understanding between the USDA and the National Association of State Universities and Land-Grant Colleges that spelled out terms for joint planning and cooperation in agricultural research. That agreement established the Agricultural Research Policy Advisory Committee--a joint body of USDA and the Association, and set the stage for joint regional and national research planning activities by the USDA and the states.

Under that structure, the parent body was composed of senior administrators of USDA and the state institutions, and was co-chaired by a state person and the senior research official of the Department, then the Director of Science and Education and later the Assistant Secretary for Conservation, Research, and Education.

That general framework was carried through in the language of Title XIV of the Food and Agricultural Act of 1977 in the form of the Joint Council on Food and Agricultural Sciences, a concept expanded to encompass extension and higher education in addition to research. The Joint Council has continued the regional and national planning activities in research, and has attempted to initiate similar activities for extension and higher education as mandated by the Act.

The research planning structure consisted of four regional research planning committees, constituted jointly by USDA and SAES administrators and a national research planning committee with similar composition. The regional structure was geographically parallel to the four regional experiment station regions. Within the regions, there were a number of regional planning groups dealing with broad subject-matter areas; and a number of task forces that drew on the scientific community to address specific problems. Similarly, at the national level, ARPAC sponsored a number of national planning efforts, most of which culminated in reports containing meaningful recommendations relative to both content, scope, and magnitude of research needed to address critical problems. The Joint Council has similarly initiated a number of studies, and brings recommendations to the secretary and to the institutions represented in the partnership.

One major development under the ARPAC operation was the establishment of a program structure that was commonly used by all participants--including the initiation of the Current Research Information System--a computerized data base that records a variety of management information. Those structures continue and are under constant review and modification to better adapt to the interests and concerns of those agencies and organizations working in the system.

It is perceived by some that the regional and national planning system that has evolved has in many respects replaced the earlier "research leadership" system in setting priorities for application of resources in the system--both state and federal. It clearly has strengthened the impact of research managers on the setting of priorities and the application of resources; and in that sense has significantly strengthened the cohesiveness and cooperation between the federal and state establishments and among the state stations. The system also reflects increasing strength and resources of the states in the total program; and, perhaps results in increased state managers' infuence in priority setting. In the process, however, the strengthening of management input has likely weakened the influence of technical leaders.

3. The National Academy of Sciences Committee on Research Advisory to the USDA

The Committee on Research Advisory to the USDA was established by the National Academy of Sciences/National Research Council, through its division of Biology and Agriculture, in response to a request from Secretary of Agriculture Clifford M. Hardin on February 10, 1969. The roster of the Committee was completed by the late summer of 1969 and the Committee held its first meeting on November 20, 1969.

The terms of reference for the Committee were to (a) examine and evaluate the quality of science in agricultural research, (b) to ascertain gaps in agricultural reseach and make such recommendations as might be appropriate, (c) to ascertain the extent to which scientists in the basic disciplines relate their research to agriculture and the extent to which agricultural scientists contribute to basic science.

The Committee was chaired by Dr. Glenn S. Pound, Dean and Director of the College of Agriculture and Life Sciences, University of Wisconsin. The Committee included nineteen members, as follows:

Dr. Glenn S. Pound, Chairman Dean and Director College of Agriculture and Life Sciences University of Wisconsin Madison, Wisconsin 53706	Plant Pathology
Dr. Stanley I. Auerbach Chief, Radiation Ecology Section Health Physics Division Oak Ridge National Laboratory Oak Ridge, Tennessee 37830	Ecology
Dr. W. M. Beeson Lynn Professor of Animal Nutrition Department of Animal Sciences Purdue University Lafayette, Indiana 47907	Animal Nutrition
Dr. C. E. Bishop, Vice President University of North Carolina Chapel Hill, North Carolina 27514	Agricultural Economics
Dr. Nyle C. Brady Director of Research and Director Cornell University Agricultural Experiment Station Itahca, New York 14850	Agronomy
Dr. N. T. Coleman Professor of Soils and Plant Nutrition University of California Riverside, California 92502	Soil Chemistry
Dr. Ralph E. Comstock Department of Genetics and Cell Biology College of Biological Sciences University of Minnesota St. Paul, Minnesota 55101	Genetics
Dr. Thomas R. Ford Department of Sociology University of Kentucky Lexington, Kentucky 40506	Sociology

Dr. Harlyn O. Halvorson Rosenstiel Basic Medical Research Science Center Brandeis University Waltham, Massachusetts 02154	Cell Biology
Professor Dale E. Hathaway Department of Agricultural Economics Michigan State University East Lansing, Michigan 48823	Agricultural Economics
Dr. D. Mark Hegsted Department of Nutrition School of Public Health Harvard University Boston, Massachusetts 02115	Nutrition
Professor Daryl J. Hobbs Department of Sociology and Rural Sociology University of Missouri Columbia, Missouri 65201	Sociology
Dr. Robert W. Holley The Salk Institute for Biological Sciences San Diego, California 95616	Biochemistry
Dr. Robert E. Hungate Department of Bacteriology University of California Davis, California 95616	Microbiology
Dr. Robert L. Metcalf Department of Zoology University of Illinois Urbana, Illinois 61801	Entomology
Dr. William R. Pritchard Dean, School of Veterinary Medicine University of California Davis, California 95616	Veterinary Medicine
Dr. Nevin S. Scrimshaw Head, Department of Nutrition and Food Science Massachusetts Institute of Technology Cambridge, Massachusetts 02139	Nutrition
Dr. Kenneth V. Thimann Provost of Crown College University of California Santa Cruz, California 95060	Plant Physiology
Dr. Paul E. Waggoner Chief, Department of Soils and Climatology Connecticut Agricultural Experiment Station New Haven, Connecticut 06540	Climatology

In addition to the Committee, eight panels were established on different subject areas, with a total of forty-three additional members. Of the sixty-two individuals involved in the review of national agricultural research capabilities --including the SAES as well as the USDA--fifty-eight were from the land grant universities, other universities, and specialized research institutes such as the

Oak Ridge National Laboratory, the Salk Institute for Biological Sciences, and Campbell Institute for Food Research (of the Campbell Soup Company). There were three USDA representatives, including one from the Agricultural Research Service and two from the Economic Research Service. One other federal scientist was from the Water Quality Office of the Environmental Protection Agency.

The composition of the NAS Committee was interesting since the Committee was expected to review the research of the state agricultural experiment stations as well as that of the USDA. In the case of the PSAC Agriculture Panel on Science and Agriculture of 1962, the review was strongly focused on USDA research.

The report of the "Pound Committee" has been characterized by some as the most damaging document of recent decades with respect to its influence on the national agricultural system. This stems from undue focus by some critics and reviewers on page 12 of the Committee report, which states:

> "The Committee found evidence that, in the allocation of resources for agricultural research, grossly inadequate support was given to the basic sciences that underpin agriculture; that the agricultural research establishment seems to have an excessive number of field laboratories with an undesirable low level of coordination and integration of SAES-USDA efforts; that disproportionate commitment of funds to some areas has resulted in undercommitment in others and thereby to weakening the vitality and the balance of the total program.
>
> "Evidence was also found that in the research itself there is an unwarranted duplication in some areas and thus a wastage of resources; that far too much of the research is of low scientific quality, indicating low ability of some researchers, or poor administrative management of the researcher.
>
> "In the area of management of scientists the Committee found very disturbing evidence of ineptness with direct impact on research quality. Administrative structures and philosophies were found that reduce the decision making power and freedom of movement of the scientists, with repressive effects on the quality of science. Programs for staff improvement, throughout the system, are either grossly inadequate, or ineffectively used, resulting in stagnation and premature obsolescence of the scientists."

The foregoing statement in the report, which was issued in April 1972, furnished the base for a number of articles in Science and in other publications during the succeeding eighteen month period. The most caustic, from "News and Comments," Science 5 January 1973 and 27 April 1973, are attached as ANNEX I and ANNEX II. The thrust, and interpretation, of the above articles was that the disparaging remarks in the report were directed toward the USDA since it was deemed unlikely that the Committee, composed largely of university personnel, would be inclined to level such damning assessments at themselves or their institutions.

The NAS Committee Report, and particularly the panel reports, reflected more concern about the freedom of action and independence of the individual research worker than with the design and conduct of mission-oriented research directed to solution of national agricultural constraints and problems.

The strong academic thrust of the Committee and the panels was reflected in many areas of the report, including the following issues:

a. The continued strong emphasis on basic research, in narrowly prescribed subject areas such as photosynthesis, nitrogen fixation, membrane phenomena, and others. These subjects, which are important and later emerged as the basis for requesting federal funding, are specialized components of the broad spectrum of agricultural science and technology.

b. The tendency to equate productivity and performance in terms of numbers of publications coming out of SAES and USDA research. While publication is an important index for performance, much problem solving research is measured in terms of more productive plants and animals, new pest and disease control practices, and similar contributions which require substantial time in the field and less time at the desk.

c. The comparison of the teaching and postdoctoral training programs of the SAES and USDA, suggesting a lack of awareness that the USDA is not expected to be a comparable teaching institution.

d. The consistently negative tone with respect to problem solving or mission-oriented research and the strong endorsement of the alternative of individual investigations.

It is unfortunate that the foregoing and the harshly derogatory items in Science attained such public prominance with respect to the NAS Committee Report. A careful reading of the Report discloses many constructively critical analyses and recommendations that would serve to strengthen the national agricultural research system. The twenty recommendations of the Committee are as follows:

1. That the USDA make appropriate changes in its research administration whereby a greater participation in the decision-making process in regard to research would rest with active researchers and with the lower echelon of administrators who are closest to the programs.

2. That the USDA in the selection of research administrators seek those with an administrative philosophy that gives maximum encouragement and freedom to the individual scientist consistent with the program mission, and that the mechanism of administrative review be strengthened so that knowledge of unsatisfactory administrators would be obtained early. We further recommend that mechanisms be developed for easy replacement of unsatisfactory administrators.

3. That the USDA "search and screen" the scientific community at large in the selection of its administrators to insure that it recruits the best scientific leadership available.

4. That the rationale for each branch station be examined critically and that unproductive branch stations be closed and resources be employed in areas of greater scientific productivity or more timely needs.

5. That efforts be made by USDA to close out many small field stations or, if their programs are justified, to transfer such program responsibilities, together with their support, into the SAES (State Agricultural Experiment Station) system.

6. That increases in federal support to the SAES via formula funds be maintained at a level at least proportionately as great as for USDA in-house research.

7. That USDA program a greater share of its in-house research on or near campuses of colleges or universities where such programs can benefit from scientific interchange with a broad spectrum of scientists and can relate to manpower training.

8. That the SAES and USDA provide greater opportunities for post-doctoral training both in terms of post-doctoral experience for staff and in using their research programs to provide doctoral experiences for others.

9. That the USDA and such legislative committees of SAES as ESCOP (Experimentation Station Committee on Organization and Policy) seek to communicate better to the U.S. Congress the harmful effects of disproportionate commodity earmarking of agricultural research funds.

10. That the USDA seek a greatly increased level of appropriations for a competitive grants program, which should include support of basic research in the sciences (biological, physical, social) that underpin the USDA mission. These appropriations should be without commodity earmarking although they should not exclude commodity related research. They should be available to scientists in the USDA, in land-grant and non-land-grant public universities or colleges and in private universities or colleges, institutes, and other research agencies.

The Committee recommends further that this program be administered in such a way that research proposals are subjected to evaluation by peer panels of selected scientists drawn from those eligible for support, and that the administration should not be the same as that making allocations for USDA in-house research.

11. That the SAES and the USDA provide greater support in their intramural programs to research in the basic disciplines related to their missions.

12. That the SAES and the USDA give attention to the need for greater integration at the working level between the agricultural scientists in the basic disciplines.

13. That the USDA strengthen its scientific personnel appointment and review system to include evaluation by broader scientific community. Administrators, since they hold final approval authority, should not serve as chairmen of personnel committees.

14. That SAES make broader use of peer judgment in evaluating scientific personnel, including evaluations pertinent to advancements after tenure. The review committees should include scientists from outside the professor's department and college. The department heads or chairmen should not serve as chairmen of the review committees.

15. That the USDA provide increased opportunity for active researchers to advance as researchers to the top salary classifications.

16. That the USDA search the scientific community at large when recruiting for open research positions at all professional grades.

17. That funds to support an effective program for staff improvement in the USDA be set aside at or above the divisional level before allocations are made for project support. Only in this way will support of the staff improvement program be protected from the pressures of operational budget needs.

18. That the SAES make greater effort to provide study leave opportunities for their research staff and that both SAES and USDA provide travel funds to enable the staff to attend national and international meetings in their fields. When necessary, these needs should be placed in high priority competition with other research and training needs.

19. That the USDA and the SAES develop, cooperatively, a new project and program review system that requires peer judgments of the scientific quality of the projects and programs. Consideration should be given to the science panel review concept common in other federal research agencies. Panel members should be qualified scientists and should be chosen from the scientific community at large, including scientists in SAES, USDA, private universities, non-land-grant public universities, and industry. They would provide judgment to the SAES and USDA on the quality of the project as a scientific endeavor. New projects should be reviewed as early as possible and in no case later than one year after initiation. Continuing projects would be reviewed every three to five years.

20. That there be broad subject matter program reviews at least every five years.

Although the language and tone of many sections of the report fostered the analyses and interpretations put forth in the "News and Comment" articles of Science --with the wide readership in the scientific community--the bottom line in the Science article of 5 January 1973 still prevails:

> "Yet if the state of agricultural research is as debilitated as the NAS committee believes, how has U.S. agricultural production come to be the marvel of the world?"

4. The 1972 Reorganization of the ARS

The 1972 reorganization of the ARS was announced through the ARS Administrator's Letter, to all employees of the Agricultural Research Service under date of April 21, 1972, which stated "after nearly two years of data gathering, program evaluation, and organizational study, we have completed conceptual plans for a new organizational structure for the Agricultural Research Service. This has been a team effort, and we are now ready to enlarge the team to complete the plans and put them into effect."

The new organization called for two major staff units at the headquarters to support the administrator's office. The national program staff, of four assistant administrators and their staff specialists, would be concerned with policy and program development, evaluation, and coordination. The NPS would be concerned with the areas of animal science; plant science; soil, water, and air; and marketing, nutrition, and engineering science. The second major staff unit would be concerned with business administration, under a deputy administrator for administrative management. Smaller support staffs were to be responsible for national phases of information, international programs, and similar assignments.

The major thrust of the reorganization was to assign the line operating authority to the field, with four regional deputy administrators, and four associate deputies, to be located within each of the four SAES regions. Each regional deputy administrator would have an administrative services staff, together with program planning, development, and evaluation staff, and information and biometrical service support.

Each of the four regions was further subdivided into a series of research area centers, under a research area director.

Since the NAS committee report was completed in April 1972, and the ARS Administrator's letter of April 21, 1972 indicated that the proposed reorganization was the result of "nearly two years of data gathering, program evaluation, and organization study"--there has been a general tendency to assume that the 1972 reorganization of ARS was based on the NAS committee report. However Glenn S. Pound, Chairman of the NAS committee, states (1979) "during 1969-1972 a study was being carried out by the National Academy of Sciences, sponsored by the U.S. Department of Agriculture and the Land Grant College Association, to determine the 'state of health' of agricultural research in the United States. The administration of the U.S. Department of Agriculture made no communication whatever of the reorganization plans to this committee. I am not aware of its seeking counsel from the Deans of Agriculture of the Land Grant Colleges, or from its own scientists."

It seems important that the record be made clear that the ARS reorganization of 1972 was independent of the NAS committee which, as noted earlier, was established in response to the request to the NAS/NRC from Secretary of Agriculture Clifford M. Hardin on February 10, 1969.

5. The Food and Agricultural Act of 1977

Public Law 95-113 of the 95th Congress defines the role of the USDA, the SAES, and other institutions in the planning and coordination of agricultural research, extension, and teaching.

The Department of Agriculture is designated as the principal agency of the federal government for agricultural research (except for the bio-medical aspects of human nutrition concerned with diagnosis or treatment of disease), with extension, and teaching in the food and agricultural sciences. The Secretary of Agriculture is directed to coordinate all agricultural research, extension, and teaching activities conducted or financed by Department of Agriculture and, to the maximum extent practicable, by other agencies of the executive branch of the U.S. government.

The law provides that the Secretary shall establish within the Department of Agriculture a committee to be known as the Joint Council on Food and Agricultural Sciences, which shall have a term of five years. The primary responsibility of the joint council is to foster coordination of agricultural research, extension, and teaching activities of the federal government, the states, colleges and universities, and other public and private institutions and persons involved in the food and agricultural sciences.

The Secretary also is directed to establish within the Department of Agriculture a National Agricultural Research and Extension Users Advisory Board which also is to have a term of five years. The Advisory Board is responsible for preparing independent advisory opinions on the food and agricultural sciences.

The Joint Council and the Users Advisory Board are functioning and their third annual reports were submitted late in 1980. The Joint Council has set up three national functional planning committees and four Regional Councils. The purpose is to determine local, regional, and national priorities, and to foster cooperation and coordination among the participating agencies. In the actions to date by the Joint Council there has been no focus on the organizations which should have primary responsibility for work on state, regional, or national problems.

The Science and Education Administration (SEA) was established within the USDA in response to Title XIV of the Act, which emphasized that agricultural research, extension, and teaching are distinct missions of the Department. A description of the SEA is presented in the USDA publication USDA's Science and Education Administration, What It Is--What It Does. Washington, D.C., April 1980.

6. An Assessment of the Reviews and the Reorganization of 1972

There have been major changes in the organization and operations of the USDA research in the past 30 years. And the scientific leadership of the USDA--the Chiefs of Bureaus and Heads of Divisions in 1953, or the Chiefs of Branches and Investigations Leaders in 1972--had little or no opportunity to be heard and to express their judgments in the reshaping of the science and technology programs for which they were responsible. The decisions were made by a small group within the USDA--working in isolation from both USDA and SAES scientists. (But, one might ask, "Would there ever be a reorganization if everyone potentially impacted were active participants in the process"?)

The PSAC Agricultural Panel on Science and Agriculture of 1962 and the NAS Committee on Research Advisory to the USDA of 1972 were composed primarily of university people. And the 1962 and 1972 review reports had many commonalities, including the following:

a. The recommendations that USDA research stations should be shifted to the SAES.

b. The discrediting of the leadership of the USDA, reflected in the 1962 review by the strongly antagonistic attitude of the technical assistant to the panel representing PSAC, and in the NAS report which suggested that the USDA has problems in removing undesirable administrators and should open recruitment to the scientific community generally. The report stated, more specifically, "now is a strategic time for it [the USDA] to profit greatly by pulling in well-established and outstanding scientists from the university system."

c. Both reviews urged an increasing integration of research into scientific disciplines (as structured in the universities), rather than pursuing the commodity or problem-oriented research structure of the USDA.

d. The NAS report was sharply critical of practical and applied mission-oriented or "directed research"--that of priority to society, Congress, or administrators. The report stated that greater priority should be given to projects developed on the initiative of scientists and assessed in peer review committees.

e. In further addressing this viewpoint, the NAS Committee recommended against the practice of earmarking of funds, particularly for commodity research. However, this stand on earmarking was inconsistent since the Committee urged greater funding for such fields as photosynthesis, nitrogen fixation, and other similar areas.

f. The NAS review tended to measure research progress or quality on the basis of publications. This does not reflect the difference between the strongly mission-oriented or problem-solving research of the USDA, which produces results primarily by improving varieties, production practices, and other advancements that are measured primarily in the field rather than in a paper. It reflects also the evolution of the land grant institutions from essentially agriculturally-oriented to large university or multi-versity systems.

It has been suggested that one major rationale for the ARS reorganization of 1972 was the increasingly burdensome task of administrative management--budget, fiscal, and personnel--as ARS programs had expanded. This is borne out by the third paragraph of the Administrator's Letter of April 21, 1972 which states:

> "When ARS was first established in 1953, our research budget was approximately $32.4 million and our total staff was less than 4,000 employees. Today, our basic budget is approximately $173 million. With special accounts, foreign currency programs, etc., there is a total budget of just under $200 million and a staff of over 10,000 employees at some 105 locations. During this nineteen year period, there have been essentially no organizational changes designed to cope with the tremendous agency growth, both in its size and in its program complexity...."

By 1980, there was some reduction, to 9438 employees in SEA, with 8970 in AR at 148 different locations.

The effect of the reorganization was to relegate the former national program "investigations leaders" to national program staff positions, removing their line responsibilities and authorities with respect to program development, budgeting, selection of staff, etc. It was stated that "The research investigation leaders concept would be retained and strengthened by placing the research leaders out in the regions where there can be more frequent and sustained leadership activity. National coordination will come through the national programs staff." This reflected a lack of understanding of the national function of investigations leaders who gave attention to such commodities as wheat research which long had involved leadership at the national level as well as in the respective regions concerned with specific classes of wheat, or cotton research which extends from the southeastern U.S. through the southern states and into the western region, in the states of Arizona and California.

There was lack of awareness that the national investigations leaders, as pointed out by Dr. Howell in the discussion of soybean research, were not merely staff functionaries but actually respected and involved scientists providing a professional leadership role in the cooperative endeavors. Dr. Howell stated that the 1972 reorganization, whatever its merits, disrupted the channels of communication and arrangements that had evolved over several decades. No longer was there a clear path to the leadership of soybean research and it is also much less likely that potential leaders have a working environment which fosters their emergence as recognized leaders in the pattern of Weiss, Johnson, and Caldwell.

The architects of the reorganization failed to assess and take into account the experience in the establishment of the Agricultural Research Administration in 1941, when the ARA technical staff "coordinators" proved to be relatively ineffective after a few years because they were so far removed from the actual research programs--and the similar experience in the reorganization of 1953 when the centralization of the former Chiefs of Bureau into the Agricultural Research Service, in a staff capacity, placed these persons in unproductive positions--serving neither the research branches or scientists under them, the research administrator and others at higher levels in the Department, the Budget Bureau and Congressional Committees, or the cooperating SAES. The experience within the USDA for 30 years--from 1941 to 1972--clearly demonstrated the ineffectiveness of such an organization and staffing pattern for national research management.

As stated in the NAS Committee report of April 1972 (Page 16), the bureaucracy of research administration in the USDA becomes increasingly burdensome with each succeeding reorganization. The reorganization in April 1972 has been operating for nine years--a sufficient time span to justify an assessment of the current SEA/AR structure with respect to the overall national research system and the respective functions of the SAES and the USDA. The following statements, by scientists who spent the last thirty years of their careers in USDA research, in positions of respected leadership in USDA/SAES cooperative programs, but who are no longer employed by the USDA or the SAES components of the research system, seem relevant:

> "As a consequence of various changes, the research role of the USDA is poorly understood not only by people outside the Department but also by scientists and administrators within the Department. This reflects changes in leadership responsibilities and in the quality of leadership that the Department has been able to attract with the absence of a clear mission. Currently, any semblance of national orientation on specific commodities and problems must be credited to the carryover of research personnel from programs initiated prior to 1972.
>
> "The Department has not made a serious attempt to chart a course that would be apparent to both SAES's and the private sector. In fact, a conscious effort has been made to integrate State and Federal functions to the point where there is no clear separation of scientific personnel. This is laudable where it entails cooperative research, but today many federal scientists tend to be oriented toward local issues rather than to broader national problems. An increase in local orientation has increased duplication of projects, specialized facilities and expensive equipment.
>
> "The Department has become obsessed with counting heads and dollars assigned to various projects and/or commodities, because it is not in a position to make definitive technical assessments of quality. Conversely, we know all too well, that research and progress in research is a function of the quality and motivation of people who can be attracted and retained in an organization.
>
> "The present organizational structure virtually prevents the emergence and recognition of strong national and international leadership by USDA scientists. Technical capability at the national level is now largely limited to the National Program Staff. This staff represents the core of scientific competence in various areas of specialization that represent agricultural research as a whole. Unfortunately, however, these scientists are so burdened with day-to-day demands for technical information required by the various administrative offices that they do not have time to remain abreast of and critically analyze research program needs and objectives. Many of them do not have time to interact in depth with research scientists in identifying research approaches and in defining long-term strategies. They have important responsibilities but little real authority in the planning, implementation and direction of a national agricultural research program. As one member stated, "My influence in shaping USDA's research is a continuing 'exercise in diplomacy' rather than real authority." Current decision making on research priorities and needs rests largely in the hands of personnel far removed from scientific personnel and actions.
>
> "The research scientists within the USDA are continuing to develop basic and applied information that is of immediate and long range significance to agriculture in all of its aspects. However, the efforts to achieve more effective interdisciplinary cooperation between USDA scientists and ostensibly to facilitate cooperation with State programs, through the major reorganization that was implemented in 1972, in my opinion, has been counterproductive. Research leadership in such areas as entomology, agricultural engineering, weed sciences, and animal health, was decentralized at the national program level and largely transferred to area and regional levels, in an apparent effort to more effectively serve commodity-oriented research.
>
> "The importance of adequate coordination of research by scientists in various disciplines that are working toward broad goals and objectives cannot be overemphasized. However, this can and should be accomplished without destroying the opportunity for optimum coordination and cooperation by scientists engaged in disciplinary research, and without lowering the presitge and morale of the scientists who represent the foundation for a strong and viable agricultural industry."

The USDA publication of September 1980 describes how the SEA/AR is set up and intended to operate. But the foregoing statements from outstanding agricultural scientists experienced with the national research system--provided in July 1980--suggest that the system is not working effectively.

Another assessment of the national agricultural research situation that merits reflection was given by the late Dr. K. S. Quisenberry (in personal correspondence with the senior author on March 21, 1976). Dr. Quisenberry spent his early years working on farms and in flour mills around Newton, Kansas, an area into which turkey wheats were introduced by the Mennonites in the latter part of the 1800's. He spent eight years at Kansas State Agricultural College on his B.S. and M.Sc. degrees and was hired by the USDA to work in wheat improvement research following graduation. Subsequently, he served as the investigations leader for the Hard Red Winter Wheat Improvement Program of the Great Plains. He travelled widely throughout the area from Texas into Canada, and for 10 years was located at the Nebraska Agricultural Experiment Station. Subsequently, he served as Head of the Division of Cereal Crops and Diseases of the USDA, then as Assistant Chief of the Bureau of Plant Industry, Soils and Agricultural Engineering. He was Director of Crops Research prior to his retirement from the USDA after more than 40 years of service. During most of this time, he was involved in the close cooperative research of the USDA and the SAES, and did much to foster and maintain these cooperative relationships in numerous national and regional programs. In March 1976 he commented:

> "I am up to my ears in history now. My present problem is a study of the old Dry Land Agriculture Office. I will give a paper in June at Bozeman before the Agricultural History Society. And the more I dig into the story, the more respect I have for the job DLA did, and the vision of Chilcott and others like Jardine, Farrell, Cardon, Burr, Zook, Halstead, and many others."

And he further stated,

> "Each time I come away from Beltsville and Washington, I am more depressed over the way I see ARS--too many chiefs and too few Indians. Also, I see it as an almost complete victory of the experiment station directors over ARS. I am glad I was not there when it started to happen."

The foregoing comments are presented here, not because all of the co-authors necessarily agree with them, but because they were offered by a person who had spent many years in a leadership position in the national agricultural research system. They reflect a disappointment that the many years of mutual concern and effort of the USDA and SAES to maintain a strong collaborative partnership had degenerated into what he perceived as an antagonistic and destructive relationship. As he stated on another occasion, "it took 110 years to build the system--with an effective national capability provided by the USDA through the investigations leaders and others with a broad perspective of problems and research needs throughout the country--and less than 3 years to tear it down."

It is probable, in the view of the senior author, that Dr. Quisenberry assumed--from the timing of the NAS Committee Report and the announcement of the 1972 reorganization of the ARS by the ARS Administrator--that this reorganization reflected the NAS committee (Experiment Station Scientists) recommendations. As Pound (1979) points out, this was not the case.

There appears to be, in the view of many both inside and outside the system, a growing sense of competitiveness or antagonism between the USDA and the SAES, a relationship that may well be enhanced by the lack of significant increase in agricultural research budgets in recent years and the resulting competition for limited funds in the face of escalating costs for research.

The image of competitiveness and agressiveness of the SAES and other universities has evolved over a substantial period of time--it is reflected not only in the relationships with the USDA but also with the USAID.

The changing relations with the USAID, with respect to the role of the universities in foreign aid efforts, have evolved from the time of the study by Dr. John W. Gardner, culminating in his report "AID and the Universities" in 1963; through the International Rural Development Conference, sponsored by the AID in July 1964, in which efforts were made to evolve more effective AID-university relationships; and through a number of more recent actions that have tended to be less cooperative and more progressively competitive.

The perception of growing competitiveness is held by many relative to the posture taken by some universities that led to the inclusion of Section 211 (d) in the Foreign Assistance Act of 1966, providing funds to build the capabilities in universities for foreign assistance work, and the more recent passage of Title XII in the Foreign Assistance Act amendments of 1975. On the other hand, many within AID and the university community view these developments as a response to major policy and programming decisions within AID. Included are (1) the major shift from institution building and related technical assistance activities to a program heavily oriented to capital transfers during the early years of the Kennedy administration, which persists in significant measure to the present time, (2) the deliberate policy decision by AID of the Kennedy, Johnson, and Nixon administrations, and persisting to the present, to reduce technical personnel within AID in favor of program performance by contractors, (3) the emergence of the so-called "new directions" or "mandates" which led programs away from the type in which universities and/or USDA had a comparative advantage to types of activity which provided direct benefits to "the poorest of the poor," such as, water and sanitary systems, transportation, and direct aid to individuals and communities. Many view the recent response of the universities--and many in AID--to those policy matters as a recognition that the agency needed to shift back to programs that, through institutional development, would have more lasting impact. Given the continuing decline in technical expertise within AID to conduct or guide programs, the universities became one viable alternative.

The AID-university relations are complex, with many interactions that are not widely recognized. The Section 211 (d) and Title XII amendments were presented to the Congress with strong assertions or implications that the universities have the capabilities and resources to carry out technical assistance programs more effectively than does AID through its direct-hire operations. This has had a deleterious effect on foreign aid because it tended to preclude employment by AID of the kinds and numbers of agricultural scientists and other specialists who are essential in the long-term staffing of USAID missions abroad, where they can develop a depth of understanding not only about the constraints to agricultural productivity, and the nature and relevance of agricultural science and technology, but also an in-depth understanding of the institutional and social factors involved.

While the participation of U.S. university personnel in AID activities is not strictly a concern of the current OTA study, the impact of this involvement on the focus of SAES resources on problems of their respective states is a matter of concern. University policies that foster such participation must accommodate such activities without significant impact on on-going SAES programs.

It would be unfair and unrealistic to suggest that the competition between the USDA and SAES is the major factor that has been deleterious to the operation of the national agricultural research system in recent years. But there is need for a serious self-assessment of the current organizations, operations, and policies--of the USDA, the USAID, and the SAES--with respect to their respective basic charters and to relationships in programs of mutual concern.

In his Cosmos Club Lecture of April 1980, Dr. John W. Gardner addressed the subject of "The War of the Parts Against the Whole." This is interesting and relevant reading, and so has been included with this paper as ANNEX III. Dr. Gardner notes the continued development of various "groups" that have expanded in number and diversity following World War II--and in their capacity to organize for combat. The following comments from his paper are of special interest:

> "In most of these groups the element of cohesion is supplied by a common economic activity or interest. But others seek redress of grievances that they have suffered at the hands of society. And then there are the 'issue' groups, members of which may come from diverse social, economic, or occupational backgrounds, but have in common a shared concern for advancement of a particular public policy.
>
> "I want to emphasize that most of the groups have legitimate concerns: some of them have concerns that are, by any standards, urgent. But as more and more of them learn how to organize for effective action, and how to slug it out on the adversary mode, what started as healthy competition has developed destructive aspects. If we can't face that fact, we're lost.
>
> "The war of the parts against the whole is a central problem of pluralism today. We're moving toward a society so intricately organized that the working of the whole system may be halted if one part stops functioning. Thus our capacity to frustrate one another through non-cooperation has increased dramatically. A part can hold the whole system up for ransom (as the air traffic controllers, among others, have so vividly demonstrated).
>
> "All of this is ironic when one recognizes that never have so many of these groups been so highly organized and effective in action. They know how to lobby. They

> know how to "use" the media. They establish "beach heads" in government agencies, sometimes even force reorganization of an agency to suit their purposes. And they effect public policy.
>
> "It is entirely legitimate for such groups to organize themselves. It is their constitutional right to seek to influence government, and often what they want is not unreasonable. But what can we do when the factional strife becomes more than the system can bear?
>
> "All too rarely have any of the organized groups shown the slightest concern for the health of the political process. All too often they have been satisfied with incompetent, disorganized or even corrupt government, provided that they could influence it.
>
> "Our pluralistic philosophy invites each organization, institution, or special group to develop and enhance its own potentialities. But the price of that treasured autonomy and self-preoccupation is that each institution concern itself also with the common good. That is not idealism: it is self-preservation. The argument is not moralistic. If the larger system fails, the subsystems fail. That should not be such a difficult concept for the contending groups to understand."

The article by Gardner applies to the relationships between the USDA and the SAES. Of greater importance, however, may be the effect of the self-inflicted dispersal of the USDA research resources and authorities, with substantial autonomy in the regional and area offices. This weakens the conceptual, operational, and coordinating functions that should be carried out by the USDA for national and regional programs. Of perhaps equal significance--and more difficult to resolve--is the effectiveness of the institutional structure in the SAES. With the growing pluralism and academic freedom that has been essentially recognized as a right in the U.S. universities today it is not uncommon to hear senior university professors deprecate the deans and directors of the SAES, and university administrators, by asserting that they are irrelevant and nonproductive--concerned primarily with clerical activities in keeping track of funds and spending the major part of their time with committees. The availability of grant funds from various federal agencies to individuals or to selected groups of persons for basic studies--particularly in the earlier years in fields outside of agriculture--has impacted the institutional and leadership structure in many universities. Research in state agricultural experiment stations cannot be "directed" in the sense that it once was.

Dr. Don Paarlberg (1980) in commenting on the paper by Bertrand (1980) presented for the 1981 Agricultural Outlook Conference in November 1980, also recognizes the importance of strengthening the alliances and mutual support of the components or sectors of agriculture. Dr. Paarlberg states,

> "When the Land Grant College system was set up farmers totalled 59 percent of the population. The farm population has fallen so that it presently equals 2.8 percent of the total. And it is still declining. There may have been a time when quarrels between the various sectors of agriculture could be indulged. Not so at present, nor prospectively. This is not a time to stitch together a patch-work quilt. And it will have to be a quilt suited to the needs of today and tomorrow, not of yesterday. Only then will we be able to merit and obtain the resources needed to do the job that Dr. Bertrand so persuasively outlines for us."

A very basic, and most difficult, aspect of the present study is to somehow realign the parts into the whole, within the SAES and within the USDA, and to restore a cooperative relationship between the SAES and the USDA that is built on a mutual respect and awareness that each of these important partners has a significant and well-defined role in the national research system. Unless the USDA and the SAES exercise the discipline required to establish their respective "self-identities" and primary responsibilities they cannot expect congressional appropriations committees to determine who should be given how much funding to do what research.

C. New Dimensions in SAES Programs

1. The McIntire-Stennis Act

Passed in 1962, the McIntire-Stennis Forestry Research Act authorized special formula funding for forestry research in the SAES, to forestry schools in certain non-land grant public institutions, and in selected private colleges and universities. It singled out a companion program to that of another USDA research agency, the Forest Service, for special attention and related those programs to each other in special ways, including guidelines on relative funding for each, even though forestry research was fair game under the Hatch Act and related legislation. It was also the first in a series of legislative and executive actions leading to a broadening of the base of institutions participating in formula and other specially funded programs along with the SAES.

2. Other Broadening Authorities

The Special Research Grants Act, P.L. 89-106, of 1965, authorized grants to SAES, "other public institutions, and individuals" to perform research on problems of concern to USDA. It in many respects duplicated authorities of the agency but at the same time offered a vehicle that has been extensively used to concentrate special efforts in the SAES and elsewhere on commodity-based or other problems of special interest to limited groups, thus largely avoiding earmarking of formula funds to special interest concerns.

Title V of the Rural Development Act of 1972 was another attempt to highlight an area of special concern, namely the economic and social problems of rural people and communities. A unique feature of the legislation was the stipulation that the effort would be a jointly planned and executed program of the State Experiment Stations and Extension Services. Although viewed by many as a useful approach and a much needed effort, there has been sufficient reservation on the part of some to prevent it receiving the priority for funding that it likely deserved. Recent executive and legislative actions suggest that decisions on both the level of and the framework for programs in this area may be returned to the State Experiment Stations and Extension Directors.

Finally, Title XIV of the 1977 Farm Bill became a vehicle for authorizing a variety of special interest programs. Most important of these are:

a. The institutionalization of research and extension in the 1890 land grant colleges and Tuskegee Institute whose participation in USDA funding really began only in about 1970.

b. Special authorizations for animal health and disease research which specifically builds in involvement of the Colleges of Veterinary Medicine.

c. The establishment of a thrust in food and nutrition research and extension in the USDA in cooperation with the states.

d. A variety of special authorities for research and/or education programs on energy related matters, the first general recognition of the USDA's potential to contribute in that general problem area.

e. The first clear authorization for USDA's involvement in international agricultural research and extension programs, along with other federal agencies including USAID.

f. A variety of competitive grant programs, both in research and education.

3. Directed vs. Competitive Grant Programs.

The in-house research agencies of USDA have had and exercised authority to contract out research on problems of special interest and where expertise existed in the universities or other research institu-tions. Such research contracts took one of several forms. In cases where there was a strong element of cooperation in the research between the agency and the cooperator, cooperative agreements were generally used. In other cases, a research grant was the appropriate vehicle and the output was the documented results of the research. In still other cases, the development of a product or process was the expectation and a contract for such a development was the form.

Prior to the passage of P.L. 89-106, authority for problem-solving grants or contracts was limited to the research performing agencies. Authority did exist in the form of P.L. 85-934 for the agency administering Hatch and other formula funds to request appropriations for "basic" research, but that option was never exercised. Even in the first request for competitive grants, the request was a part of the SEA-AR (then ARS) asking but with the understanding that the funds would be managed by CSRS. Recent requests have been made under the authority of P.L. 95-113.

The impetus for a competitive grants program grew out of the conceptions put forth in the series of critical studies beginning with the PSAC study of 1962 and further stressed in the NAS study (Pound Report) of 1972. Those and other reports alleged that the agricultural research system was neglecting so-called "basic" research opportunities and second that the system would profit by and should be opened to capture basic science competencies of colleges and departments in Land-Grant and other universitites not participating in the formula programs.

The notion of a program modelled after NIH/NSF was, of course, attractive to those outside the "system" and pressures were brought to bear on the Department and the Congress to use such a device to accommodate to the perceptions put forth in the several reports.

There is, of course, a growing consensus on the need for fundamental breakthroughs in biological and in physical research on which to build future practices in agriculture. And there is obviously much scientific talent in the sciences in universities that could be tapped to contribute to the basic pool of knowledge. Further, the ability to access USDA resources could aid in building linkage between scientists of the SAES and the USDA agencies and those of the broader university community. Those are the pro arguments for a competitive grants program.

On the con side, there are arguments put forth as to the inefficiency of the competitive mechanism, the potential discontinuity in funding when the need is for longer-term commitments, and the potential for degrading formula funds in favor of the competitive model. Each of these seem to have at least some basis in fact, even to the appearance in the initial request for competitive grant funds that the request was exactly offset by a reduced asking in the base programs.

All things considered, the competitive grants program can and should be a useful adjunct to the total efforts provided that:

a. Sufficient funds are made available to provide a truly critical mass of effort on key areas of concern including several not now included.

b. Such areas be carefully selected to include those where breakthroughs would have large impact.

c. Funding for such efforts not degrade the basic problem-solving efforts of the agencies or stations.

d. Continuity of funding to individuals or groups be accepted as a requisite in such research, recognizing that major accomplishments in such research have a time horizon of ten years or more.

e. Mechanisms be developed to link the competitively-funded research to related on-going efforts in the agencies of the department and in the stations and forestry schools.

4. Outside Influences--Social and Economic

Particularly since about 1965, the state stations' programs have been impacted and shaped by a number of outside forces. These include most notably:

a. Environmental concerns--ranging from chemicals to water and air quality to aesthetics and the regulatory and legal acti-vities related thereto.

b. The spectrum of equity and civil rights concerns--ranging from equal employment opportunity to ethnic equality and small and part-time farmers. These forces have had a real and lasting impact, both consciously and subconsciously, on both state and federal programs.

c. The concerns of consumers, which have brought impetus to food quality, safety, and nutrition research.

d. The changing structure and volatile economic events of the 1970's.

e. The resurgence of university participation in international technical assistance programs of the federal government and other donors.

Each of these has affected the form and content of station's programs. Some have been positive forces in focussing attention on neglected areas. Others have had negative effects in creating devisiveness within and among programs. On balance, however, one would generally judge the overall impacts to be positive since the forces at play have resulted in a studied self-examination of what business the system is doing and how the system is doing its business.

D. Research and Development in the Private Sector

1. The Nature and Scope of Private Sector Research and Development

The four principal sources of support for agricultural research are generally recognized as (a) the USDA, (b) the SAES, (c) the private foundations, and (d) the food and agriculture related industries. The programs of the first three types of organizations are well documented and can be classified with a satisfactory degree of precision from the standpoint of the extent and content of the programs. However, the industry research programs are not so well documented and so in this paper they have not been presented within the same time span framework as the discussions of the USDA and SAES research.

There is a general awareness of the very significant substantive contributions of the private sector to the productivity and efficiency of American agriculture through the invention, improvement, and manufacture of farm machines; through involvement in selection and improvement of a wide range of crop plants and animals; involvement in a wide range of chemical industries, including development and production of fungicides, insecticides, herbicides, animal health products, fertilizers; in animal feed and human food processing, preservation, production, packaging, and marketing; in the development and improvement of a wide variety of farm structures; and in many other fields.

The National Science Foundation makes regular and consistent efforts to evaluate industrial research programs, covering not only agriculture but also information on total industry research programs within the country. These reports provide a great deal of information but details are generally lacking.

In 1966, the Agricultural Research Institute attempted to get precise information on the extent and type of research in the food and agriculture areas. This included related industries as well. Impetus for this study came from a request from the Senate Committee on Appropriations to the Secretary of Agriculture in 1965 to establish a research review committee to examine the research programs in the USDA and the SAES. It was decided that this study should be handled by a joint committee of the department and the experiment stations. This joint committee recommended that a comparable study should be made of agricultural research in the private sector. The Agricultural Research Institute accepted the challenge to conduct this study.

A list of some 825 private organizations which were considered to have research programs was compiled, based on a breakdown of classifications which included: (a) plant breeders, (b) plant food, (c) animal feed, (d) feed ingredients, (e) chemicals, (f) animal health, (g) human food, (h) machinery, or equipment, and (i) building equipment or supplies.

The questionnaire that was developed asked for a considerable amount of information which is generally considered as confidential in industry. Private industry, for competitive reasons, cannot divulge the exact fields in which they are conducting research programs and cannot divulge the extent of interest in a particular line of work in a given time. Also, there is a reluctance to discuss research programs with competitors because of the ever-present threat of accusations of collusion and anti-trust violation.

In order to overcome this reluctance, the Agricultural Research Institute agreed that the summary reports would not be associated with the company making an individual report. After the study was completed, all of the original reports were destroyed by the Agricultural Research Institute. In a way this was unfortunate because much valuable data was lost.

About 40 percent of the companies engaged in research responded to the questionnaire. Extrapolations from the reports indicated that the private sector was expending about $460 million in research, which was somewhat more than the budgets of the USDA and the SAES combined at that time, in 1966. It was indicated that about 9 percent of the funds were expended for basic research, 50 percent for applied research, and 41 percent for engineering and development. In projecting research expenditures to 1975, the industries indicated that they expected to spend 12 percent more in basic research, 49 percent more in applied research, and 39 percent more in engineering and development in 1975 than they had in 1965. Major fields of interest in industry research were chemicals, feed, pesticides and fertilizers, machinery, and forest products. The emphasis on agricultural chemicals was on the protection of plants and animals. Food research was concentrated largely on product development and processing, with some emphasis on efficient production. In general, the work conducted by industry tended to complement the work done by the USDA and SAES. Very little research by industry is done in the social sciences.

In 1976, the Agricultural Research Institute felt that it would be timely to update the results of the survey obtained in 1965. A committee representing a broad spectrum of types of business in the agricultural industry provided a list of about 1,200 names of companies that might be contacted. The response to the 1976 questionnaire was not at all satisfactory. This seemed to have reflected the reluctance in industry to discuss their research and development activities, as mentioned previously. Further, because of the tremendous increase in the number of reports that industry is required to provide for regulatory agencies, many of the companies could see no particular benefit accruing to them to justify the expenditure of personnel time, labor, and cost to provide such information. Only 169 of the 1,200 companies contacted provided usable data.

Since the response was deemed inadequate, a less extensive questionnaire was prepared, concentrated on the more basic questions of company size, research expenditures, number of employees, and research conducted. Of the 240 companies reporting, the total R & D expenditures were $575,044,000. This represented approximately 1% of the sales of those companies. Research in animal health represented 6.3% of total sales in the companies concerned with that area. The next largest group was machinery or equipment, with 2.4%, followed by the buildings, equipment, and supplies industries, which spent about 1% of their sales in research programs.

It was felt that the returns on the survey in 1976 were not sufficiently extensive or representative to justify extrapolation to the entire industry, so the results were presented on the basis of only those companies reporting. Therefore, there is not a good comparison between total amounts spent by the agricultural industry and by public funding agencies from 1975 to date. In the 1976 survey, industry reported spending 10.2% of their total research budgets for basic research, 29.9% for applied research, 51.2% for developmental research, and 16.1% for quality assurance. The slight increase in the portion of the industry budget spent for basic research was somewhat less than had been predicted for 1975 in the 1966 survey. This indicates some decrease in enthusiasm for increases in basic research programs that had been evident in the 1966 report. Another factor, however, was the cost of "defensive research" required to meet government regulations. About 4.2% of the research classed as basic was indicated to be of a defensive nature. In the applied research area, 6.6% was spent on defensive research and, in developmental research, 8.4%. The latter figure would be primarily expenditures made in defense of existing products.

Ruttan (1980) has provided as excellent assessment of the information available on industry research programs, again pointing out the need for more accurate estimates of industry expenditures. His estimates indicate that expenditure in food and agriculture research (by industry) may total 1.6 to 2 billion dollars per year - a figure which includes product development.

It is anticipated that industry will increase the amount of money spent on grants or contracts for other agencies, to perform research of interest to industry and some increase in funding for the research that industry does for other types of agencies. One of the factors affecting the uncertainty of such funding is the increasing attack by some members of academia and by some public service groups with respect to results obtained when industry funding has been provided, or when research work is done by industry. This could result in an increase in the amount of research done by industry for the benefit of an individual company, with no publication of results. This would be regrettable, both from a standpoint of lack of availability of good information and also interrupting or decreasing communication with the public research groups. It also would be a decided increase in the cost of research because of the need for each company to duplicate the research work of others, all of which must eventually be paid by the consumer. This is an area which should receive very intensive study. The importance of a free and open relationship between research in industry and that of the public sector is highlighted in the National Science Board Report, as follows:

> "Most U.S. R & D expenditures take place in industry. Also, technology generated by industry is a principle means by which scientific research reaches the public--in the form of new or improved products, processes, and services. Industry generates much new technical information within its own laboratories, but it also receives information from outside sources such as the published literature, contractors' reports, academic and private consultants, and the hiring of skilled personnel. These transfers of knowlege are vital to the improvement of industrial technology, particularly in high technology industries.
>
> "Within industry, R & D produces technical improvements in products, processes and services. However, major improvements developed through R & D require the subsequent steps of engineering design, production engineering, prototype testing, manufacturing startup, marketing startup, and financing before they can reach the public on a commercial scale. These steps nearly always cost much more than the original invention. Technical innovations, in turn, are the source of the economic and social benefits that industrial R & D brings to the public. Innovation is of considerable interest to the federal government. There is concern that the United States may not be sustaining a sufficiently high rate of technological innovation or that the direction of innovative activity may not be appropriate to national needs."

Different segments of the agricultural industry perceive their roles in the above descriptions somewhat differently. In the chemical industry, which has a very important role in the areas of preservatives, pesticides, animal health products, and plant protection compounds, the research programs generally start with a basic consideration of the characteristics of the final product required--such as the charscteristics of compounds which may be candidates for particular functions as pesticides. The basic discovery, identification, and characterization of such compounds is considered to be in the province of the chemical companies themselves. The development of efficiency data, of toxicity data, and safety--all data necessary for clearance for use, and data on cost--have generally been considered to be within the province of the industry developing the products. However, in cases where plant protection products may be used simultaneously with other compounds which are used for other purposes, each developed by a different company, the general feeling is that it is not the responsibility of any one company to determine what the total effects of such combinations (synergistic actions) might be. This is perceived as an area where public programs of research should be involved. At the same time, the industry has felt that public sector participation is completely justified and necessary in:

a. Providing guidelines for the evaluation of safety of products.

b. Providing evaluations of relative effectiveness of various compounds.

c. Providing information on synergistic effects of multiple usage.

d. Providing efficacy and clearance data for products to be used on minor crops which are essential or desired but profit from total sales were not projected to recover the cost of clearance.

e. Developing alternative methods of pest control such as the biological methods and, more recently, acceptable integrated pest management systems.

In the past, there has been quite a program of testing products of industry, by both the USDA and the SAES. As an example, the effects of antibiotics in the feeding of farm animals to improve growth and feed efficiency. This work was justified in the early stages of the development of this concept because of the need for comparative information among the users of such products. This cooperative testing program has generated a great deal of controversy. First, there is the problem of recommendation of proprietary products by public institutions. Secondly, in the case of antibiotics used for improvement of growth rate and feed efficiency, the policy has been criticized because of concern that the use of low-level antibiotics might produce a resistant species of organisms which could render the antibiotic much less effective in the treatment of humans for certain diseases. These opinions have been neither proven nor disproven, according to recent Academy of Sciences reports. However, it has pointed out one basic lack of information. No one has determined just why very low levels of antibiotic feeding to animals produce improved rates of growth and feed efficiency. If the mode of action were known, much of the criticism could be answered positively or negatively. This is an area where Congress has directed a public agency to do research work which would provide answers to the questions.

In other segments of industry, such as the food industry, the research programs are more concentrated on applied and developmental types of research. Much of the technology in the food industry is adapted from other sources, such as the manufacturers of equipment, preservatives, and so on. The agriculture and food, and related industries, have developed as a result of the desire of the consumer for certain types of products and services. This carries with it a responsibility for industry to provide safe and effective products at a minimum cost to the consumer. For such research and development, industry must utilize all of the available information, and in some cases provide the necessary information that is lacking.

2. Agricultural Chemicals

The 1965 survey of the Agricultural Research Institute was made during a period of very intensive activity in research in agriculture and related fields. This was a time in which the role of feed additives such as antibiotics, hormones, anthelmintics, and so on were being investigated and developed to promote better growth, feed efficiency, and health in livestock populations. This was also a period in which pesticides and herbicides were being investigated, identified, and developed. There was a great deal of optimism with regard to development of new compounds which would be more economical and more effective than those currently in use. This effort was shared by both the public and private sectors. But a major activity in the development of materials was in the private sector.

As discussed previously in Chapter III, there was a widespread public concern with respect to the use of agricultural chemicals, precipitated by the publication in 1962 of Rachel Carson's book, Silent Spring. While a major problem related to the excessive application of certain chemicals, particularly pesticides, the improvement of instrumentation and methods of detection of minute quantities of components of pesticide materials created a greater awareness of potential hazards. Some of the problems were and are real, some are figments of the imagination. Thus, a new term appeared in the research literature, that of "defensive research." This is particularly true in the animal health industries. This industry reports that 11 percent of their sales dollar is spent on research. Further, in 1968, 31 percent of cost involved in developing a drug was spent to satisfy the demands for absolute safety. In 1974, safety data had grown to 50 percent of the cost of developing a new drug. In 1974, the members of the Animal Health Institute spent more than $73 million for research and development, but no new drug entities were approved by the Food and Drug Administration. In 1977, $91 million was spent for research and development with the same results. This is illustrative of the type of research investment or cost in the drug and chemical industries, the costs that must be paid by the consumer.

Limited markets or costs of federal or state regulations may make it impossible for industry to recover the costs it incurs in developing new products. The federal and state research agencies definitely have a role in developing these products. A case in point is some of the more specialized pesticides where the costs of introduction are such that sales can't possibly recover the cost of development, but yet these compounds are needed even in integrated pest management programs to effectively protect vital crops. The USDA and SAES certainly have a role in assisting in research on problems vital to the national economy. And even though the impact may be local in nature, federal research has a very definite role to play.

A further area of priority attention from publicly supported agricultural research relates to federal regulations. Where federal regulations need supportive research this should be accomplished by the national research system.

3. Farm Mechanization

The cooperation between the USDA, SAES, and private industry in the development of agricultural chemicals, and in some other selected fields, is well documented. Less well understood is the interaction of public research and private industry research in agricultural mechanization. It seems worthwhile to review some of the innovations in development of agricultural machinery and to cite the contribution of public research to such innovations. The train of events leading to each of these innovations is sometimes indistinct, but nearly all can be traced from public funding of basic research. Results of research in soils and crops (for example, soil physics and crop physiology), in chemistry, metallurgy, and other basic sciences have been integrated and synthesized by industry into practical machine applications.

The tractor is the centerpiece of farm mechanization. Although the basic form of the row crop tractor was well established by 1940, many advances have been made since that time. The active 3-point hitch for draft control was invented by Harry Ferguson in 1936, but it wasn't in widespread use until the 1950s. Engineers and agronomists had documented the damage caused by excessive ballast carried to provide traction, so a hydraulic weight-transfer hitch to reduce ballast requirements became a marketable idea. One good idea begets another, and hydraulic power took over the job of lifting mounted and drawn implements. An ergonomic study of farm activities in 1957 showed that operating a tractor manure loader was as strenuous as cutting logs, and indicated the value of power steering. Farm wives soon began to exert their inexorable pressure on their husbands and power steering as an add-on for existing tractors, and factory-installed on new ones, became universal. Engineers were quick to appreciate the design freedom of hydrostatic steering and quickly applied hydraulics to control brakes, clutches, transmissions, differential locks, and seat suspensions. The deficiencies of tractor seating were also pointed out in the late 50s and by the mid-60s truly comfortable tractor seats (grandpa could hardly believe it) came into being. Basic research in colleges and universities had pointed out a need; private development brought forth the innovations to meet the need.

Tractor overturning accidents had taken a steady toll of life and limb without much reaction until the late 50s. Farming had always been dangerous, what with horses, mules, and the variety of animal-drawn implements. Attitudes change, however, and a demand for safer tractors led to establishment of performance standards for rollover protection structures for tractors in 1967. Engineers later used the structure as a frame for an enclosed cab which can be equipped to make the tractor driver's workplace as comfortable and quiet as the finest automobile.

As cost-price pressure demanded less labor cost per acre, farmers sought more powerful, more productive tractors. Turbochargers had been used for several years in aircraft and highway trucks, but primarily to offset the loss of power at high altitudes. Tractor engineers adopted the turbocharger with a different end in mind: to increase the power output of an engine without increasing its size, thus reducing the cost per horsepower. The power shift transmission increased productivity by allowing instant gear changes without stopping. Radial ply construction became available in tractor tires, where it showed the same increases in tractive efficiency it had shown in automobile tires.

Horsepower growth required a similar growth in soil footprint to maintain tractive efficiency. Dual tires and front wheel power assist were sufficient for row-crop tractors. But higher power required a completely new tractor design: 4-wheel drive with equal sized tires on each axle, both axles power all the time.

Many implements, such as balers, combines, and forage harvesters, were formerly equipped with their own engines. The transmission driven power-take-off was less than than adequate to deal with variable loads and did not keep the machine running during tractor gear changes. The independent PTO, separately controlled by its own clutch, solved that problem and separate engines are now found only on antique implements.

Tillage tools have changes to keep pace with tractor power increases. The moldboard plow has been reshaped to work efficiently at higher speeds, eliminating the need for excessive tractor weight and ballast which would have arisen if the tractor power had been used to pull more plows at low speeds. Automatic reset plow standards protected the plow from damage when impacting a rock at high speeds.

New tillage concepts aimed at conserving soil, water, and fuel were examined by individual farmers and university researchers. Their observations led to several new tillage tools specifically designed for conservation farming. Several ingenious folding mechanisms were applied to these and other implements to make them easier and safer to transport on the highway. The slow moving vehicle emblem developed at The Ohio State University alerted other motorists to the presence of machinery moving at less than 20 mph.

Planting technology advanced in response to conservation tillage and in other areas as well. Furrow openers which can deal with untilled soil and crop residue reduced or eliminated pre-plant tillage. Seed meters that can handle ungraded seed were developed by several ingenious inventors. Central metering of seeds and seed delivery to furrow openers were applied to both row crop planters and small-grain drills, simplifying the mechanisms and seed handling. The Max-Emerge concept of controlled seed-soil contact and soil pressure built upon agronomic and engineering research at several universities. Planter monitors informed the operator of any problems, eliminating costly errors.

Fertilizer placement and metering accuracy were improved by both the development of uniform granule sizes and the use of liquid fertilizer solutions.

Both mechanical and chemical weed control have become more precise in attacking unwanted plants. Independent suspension greatly improved the ability of a rotary hoe to follow ground contours. S-shaped tines and rolling shields allowed higher speeds and reduced crop root damage. Recirculating sprayers and wick applicators complemented new herbicides and exemplified the trend to more precise control of pesticide placement.

An electronically controlled beet thinner (extra beets are weeds) was developed at the University of California-Davis, and placed in production.

Hay harvesting research has been spurred by the desire to make hay in a day. It hasn't happened, but hay conditioners and mower-conditioners have cut a day from the old three-day process. The automatic self-tying baler freed two men from the hot, dusty job of tying bales and substantially reduced the labor cost of haymaking. The bale thrower further reduced labor needs by eliminating the man loading the hayrack. Bale accumulators, loaders, and high speed self-propelled wagons further reduced the cost of commercial hay production. Hay wafering and cubing machines increased the density of the final product, reducing transportation costs. Their success required a greater knowledge of crop physiology and biochemistry, some of it drawn from basic university research. Recently, a large version of the rectangular baler, producing a 1500 lb. bale, has been introduced for the large hay user. Two self-feeding concepts--the stack wagon and the large round baler--have reduced the need for covered storage. The balanced head mower drive greatly increased mower speeds and the disc-type mower maintains that speed along with greater durability.

Forage and silage harvesting costs and quality have been improved by better sharpeners, segmented knives and drum-type cutterheads in place of the fly-wheel type. The self-propelled concept increased productivity above the limits of row crop tractor power. Air-tight silos reduced silage spoilage losses and permitted high-moisture storage of shelled corn, eliminating drying costs. Automatic silo unloaders and bunk feeders reduced the labor required to feed cattle. Grinder-mixers brought the feed mill to the feeder. Barn cleaners, tractor loaders, the hydraulically-operated manure spreader, and liquid manure systems reduced the hard work of manure handling.

Corn harvesting has changed tremendously in the past 30 years. Work at the University of Illinois and elsewhere showed that the combine cylinder could shell corn, and in 1954 Deere & Company introduced the corn head for combines. Shortly thereafter a sheller attachment was offered for corn pickers and ear corn was on the way out. Shelled corn required drying, creating a research need met by the USDA and universities, and creating a new industry to manufacture dryers. The reduced losses from early harvest more than paid the cost of drying and the new machinery. Corn harvesting was one of the most hazardous jobs on the farm. Corn pickers that plugged up with stalks and leaves led many a frustrated farmer to clean out the machine while it was running, often at the cost of a hand, an arm, or a life. Combine corn heads plug much less today and the farmer with a hook is a much rarer sight.

Both corn and small grain harvesting have been aided by self-leveling combines that ignore side slopes that would shrink their capacity. Rotary separation has increased the productivity of small-grain combines by eliminating the straw walkers. Automatic header height controls, flexible cutter bars, and row crop heads have all increased the recovery of soybeans, which still produce pods almost down to the ground. USDA research, though using a different concept, illustrated the potential for improving upon the rigid cutting platform in soybeans. The combine operator can adjust machine functions from the cab to meet changing crop conditions throughout the day.

Cotton harvesting has required parallel progress in engineering, plant breeding, and pesticide chemistry. Engineers refined the stripper as far as they could with the cotton varieties in use in the early 1930's. Then plant breeders were able to produce a new type of plant, better suited to the stripper. It was also found suitable for the pickers being developed in the early 1940's. Chemical defoliation improved picker performance and is an integral part of cotton culture. Recently, the cotton module system has reduced the cost of transportation to the gin.

Electronic monitors allow machine operators to enjoy a quiet cab without worrying that a malfunction might go unnoticed.

Undergirding all these improvements in machine performance are new materials and processes. Higher power requires stronger materials, not just bigger parts.

The fruits of this research have been a decline in labor input per unit of production, an increase in farm family income comparable to city dwellers, an improvement in the quality of farm working conditions, an increase from 11 to 65 in the number of people fed by each farm worker, and lower food costs for virtually everyone in America.

4. Cooperation of the USDA, SAES, and Private Sector

There is a generally-held concept that publically supported research institutions should attack those problems which are clearly in the national, regional, and general interest, while industry should conduct research in the applied, adaptive, developmental, and defensive areas. Responsibility for basic research is not assigned, or restricted to any particular research group. The foregoing concept, of course, leaves many gray areas. As an example, when the corn blight problem appeared in the major corn producing states in 1971, there was immediate and intense activity on the part of both industry and public-supported institutions to identify the problem and solution. This was done promptly, on the basis of information shared by the public and private research organizations with respect to the genetic base of the corn inbreds and hybrids.

The respective roles of plant breeders in private and public organizations, resulting from the Plant Variety Protection Act of 1970, are still evolving. Many companies have established plant breeding programs in self-pollinated crops. The extent to which variety development responsibility will pass from public agencies to private companies remains to be seen.

There are a number of types of research which clearly merit some public support. Among these are the problems of animal and plant health protection on a national scale, such as the problems of foot and mouth disease in animals, the hog cholera problem (which has been largely controlled through public effort), BANG's disease in cattle, and Newcastle disease in poultry. There are also those problems of protection against pests attacking animals or plants--which are specific for only small segments of the animal or plant populations--and for which resulting markets for such protection products would be too small to justify the expenditure by industry for the development and clearance of products. This has become more and more of a problem, and the decision must be made whether to provide public funding or to forego the production of some of these minor, but desired and essential, products.

Basic studies are also needed on the causes for some of the food losses that occur. This has been an area of particular controversy over the past several years. GAO has estimated these losses to be from 15 to 25% of food crops produced in this country. The ultimate customer is paying for those losses.

The real question, of course, is how to interrelate the efforts of the different components of the research programs with maximum efficiency and economy. In the past--during the 50's and 60's, and early 70's--the use of industry advisory committees was utilized quite effectively by the USDA to bridge this gap between industry and publicly supported research programs. During the past few years there has been a growing disenchantment with this type of collaborative effort. The results have not been deemed cost effective, and recent executive orders were issued to discontinue the practice of using advisory committees. More recently, there has been an attempt to bridge this gap by informal discussions with certain types of industry representation such as representatives of associations who were invited to consider specific questions at specific times. This has not been done on a continuing basis.

The Agriculture Act of 1977 established a Joint Council on Food and Agricultural Sciences and also a National Agricultural Research and Extension Users Advisory Board for advice to the USDA. These organizations are functioning but it is too early to evaluate the results of this type of representation. However, it seems that one of the shortcomings of the Users Advisory Board has been that the Congress interpreted a user as one who could apply the final results of research programs, indicating a belief that the Department's programs resulted in final products. This is not always the result of federally supported research programs as they relate to industry, and is really not a desirable usual result. Therefore, it would seem that the Users Advisory Board could be strengthened by the addition of representatives of research organizations which utilize the preliminary and basic results from the publicly supported research, to carry the programs through to application and development of products for consumer use. Industry representation is also very limited on the Joint Council. These committees are not the answer to the problem of industry involvement, nor were they intended to be. But they are the chief mechanisms for problem assessment and program development at the present time so should be made more effective by improving private sector representation.

IV. CURRENT STATUS

A. USDA

1. National and Regional Coordinated Programs

The SAES-USDA research relationships, as they evolved during the first half of the 20th century, recognized that the charter of the SAES was primarily to concentrate on the needs of the people of the states they were to serve. There was, from the early years, substantial cooperation between neighboring states on mutual problems and this was accelerated in the development of regional projects authorized by the Research and Marketing Act of 1946.

The significant feature of the USDA research to 1972, when the cooperative research was effectively guided by "investigation leaders" of the ARS branches, was the opportunity to furnish an overlay of research support--in the form of scientists, equipment, and operating budgets for research that transcended state boundaries and was of concern in the various types of farming areas. Research on cotton was conducted, and strengthened or modified, where that crop was grown.

It was recognized that agricultural constraints do not conform to state boundaries--as stated by President Elmer Ellis in 1964, "There is no such thing as a Missouri vaccine for hog cholera." Research specialists, facilities, and resources of the USDA in national or regional programs were widely dispersed. Sugarcane germ plasm and breeding research was concentrated at Canal Point, Florida, and in Hawaii, while work on diseases was concentrated at Houma, Louisiana--as well as in Hawaii when smut came into the islands in 1971. Potato genetics was centered at Sturgeon Bay, Wisconsin; a national center for breeding was at Beltsville, Maryland; and disease research and quarantine facilities were in Presque Isle, Maine. The national or regional investigation leaders--specialists in a commodity or problem area--had in-depth knowledge of their research activities, including the participating expertise of the USDA and SAES--"they knew their subject and geographic territory."

The present "regional" structure of the USDA research is superficial with respect to the agriculture of the United States--if considered from the standpoint of production, processing, utilization, marketing, or distribution--or if considered from the standpoint of natural resource use and management, environmental factors, or consumer concerns. The SAES regions furnish a mechanism for interaction between states sharing a general geographic area of the U.S., to relate to common operation and management problems as well as subject areas of mutual concern. The regional structure of SEA-AR also facilitates interaction of USDA with the SAES in matters of collective operational and management concerns and the area structure focalizes interaction with individual states. The strength of the former ARS organizational structure was its ability to relate to an individual state, and to the group of states within the SAES regions, and then to transcend these boundaries and furnish the cohesive and coordinating services and functions on a nationwide scale. The latter role is essentially non-existent at this time. And the limitation is a combination of organizational structure and staff capability.

The lack of national research leadership capability is increasingly apparent to the many scientists familiar with the U.S. agricultural research system over a span of several decades. And it is equally evident to those industries concerned with commodities or problems of national scope. An example is the view of a top official of the Hawaiian Sugar Planters Association, who states:

> "I do not understand how it was decided that a national mission could be accomplished by setting up essentially autonomous regions. There used to be an ARS officer in Beltsville responsible for sugar crops. A sugarcane (or sugar beet) producer had only to go to this officer to get information or to ask for help. And that officer had a program and budget with which to do some work. Now, even though only four states produce sugarcane, there are several area and regional officers involved in research planning, and none is a sugarcane specialist. In order to get a coordinated research program going all must be informed and then must agree. As you can guess, it just doesn't work." (It should be noted that as this was written the position of sugar research specialist on the NPS staff was vacant).

Some leaders in the SAES also recognize a significant loss of national coordinating capabilities since the reorganization of 1972. USDA "investigations leaders" were recognized de facto as national leaders by state and industry colleagues as well as by federal staff members, as pointed out by Dr. Howell in the review of soybean research. They enjoyed high prestige, based on their own achievements and personal qualities, and consequently exercised leadership and influence, i.e. coordination, well beyond their formal jurisdictions.

A question relative to current USDA-SAES relationships is whether this type of scientific statesmanship still exists, with the USDA staff enlisting full cooperation of SAES leaders in assessing problems of mutual interest--and, equally importantly, whether SAES personnel are willing to recognize that certain problems of national concern should have technical and coordinating leadership from USDA scientists.

Don Paarlberg, Professor Emeritus of Purdue University, who has had extensive experience at both the federal and state levels, in discussing the question of who should coordinate research efforts states (1980):

> "The need for some degree of relatedness in the various agricultural research undertakings is clear.
>
> "The Agricultural Experiment Stations are perhaps unique among the tax-supported research institutions. They were set up nearly a century ago, when the prevailing mood was more individualistic than it has recently become. Modern macro concepts had not been invented. The States were more important then. Central direction was anathema. Volunteerism and cooperation were in vogue. The Experiment Stations reflected their times. Traditionally, decision-making was shared among the clientele groups, the individual researcher, his Department Head, his Director of Research, his Dean, the University President, the State Legislature, and the Congress. With formula funding the Department of Agriculture had limited input.
>
> "The recent surge of tax-supported research in fields other than agriculture and in agencies other than the Experiment Stations is the product of different times: more central direction, more team activity, more macro and less micro, more concern about externalities, less emphasis on the criterion long used by the Land Grant Colleges--efficiency.
>
> "There is now an effort, on the part of those who provide the Federal funds, to bring the Experiment Stations and agricultural research generally into the modern setting, with more central direction, to have it conform to the current mood. The Experiment Stations, with their proud history, understandably resist this effort.
>
> "Some form of leadership is essential. Strong central direction and coercion are repugnant for a number of good reasons. A loose voluntary cooperative type of guidance is desirable. The accepted though much scorned word for this is "coordination". It must be excercised if the research community is to appear to the appropriations committees as something other than a group of bureaucratic self-seekers. Who should supply this coordination? In my view, the Science and Education Administration of the Department of Agriculture should exercise the coordinating role, with input from the Directors of Research at the Experiment Stations and other institutions with research capability in agriculture. The Department of Agriculture is central, it is directly involved in the acquisition and distribution of Federal funds, and it comes closer to perceiving the broad public interest than does any other unit in the system. The exercise of this role is extremely difficult. An experienced administrator will take on this role with some reluctance, as an exercise of responsibility, not assertively, as an expression of power."

The above statement expresses rather well the attitudes of the SAES and the USDA, and their roles and relationships prior to the reorganization of 1972. In a few cases programs have been continued on a national coordinated basis, where some of the subject specialists of the national program staff have maintained the initiative, vision, and vigor to keep such programs operative. These are being carried on in spite of the organizational and staffing constraints of the current organization. But they are the exceptions to the current national functions of the USDA.

2. Program Planning and Budgeting

Research program planning and budgeting will be covered in other papers. However, it seems appropriate to furnish an assessment of this subject area, as related to roles of the principal participants in the system.

The agricultural sector consists of many components, including a large number of major commodities or subject areas and many smaller ventures that appear rather insignificant from the standpoint of the total national agricultural economy. However, many of these lesser commodities are of critical importance to farmers in those areas of the country where they are grown. In past years the USDA supported research on such commodities or problem areas when, for various reasons, such support was not forthcoming from the SAES. This was true for improvement of minor legumes, research on control of diseases of hops, work on mushroom diseases, and many other similar ventures. Under the present zero-based budgeting process there is little or no opportunity to protect such less visible, minor, but important areas of research. Also, because of the development of categorical budgets, with research and extension involved, there are no strong and articulate defenders for the less visible and less prestigious areas of research.

One of the most sensitive decisions is that of determining whether industries which seem to be of minor importance may indeed be fundamental to the national economy, and the extent to which research resources should be allocated to those areas. As an example: Is research on sheep or wool problems to be eliminated on the basis that the result might benefit other sheep producing countries more than it would the United States? That misses the fundamental question completely. The question is, Is the sheep industry vital to the economy of this country, or is it even desirable? Should the minor fruit and vegetable crops be an important part of our production in this country, or should they be permitted to move out of the country because of production, harvesting, storage and transportation problems or costs, resulting in importation of such products. Should some of the newer crops such as jojoba, sesame, sunflower, and others be included in the federal research programs? Fortunately, soybean research was given continued support by the USDA and some SAES from the early part of this century. There are many other such examples. Certainly, if it is in the national interest to develop the production of such crops, the federal research establishment has a very definite role in providing information regarding the feasibility or desirability of such research programs. However, these are not the exclusive interests of the federal research establishment. There are certain crops, such as the truck crops, which are of vital interest to particular states, and those states will be involved in the research programs. Further, on some of these crops, such as the sunflower, industry assumes a very important role in determining the need for such crops and the most effective utilization and marketing of their products.

One outstanding example of research developments designed to retain an industry important to the state was the invention of the tomato harvesting machine and the development of tomato varieties suitable for mechanical harvesting. There were indications that commercial tomato production would be abandoned in California unless harvesting could be mechanized. Blaise, a prominent truck crop grower, in an address before the Agricultural Research Insititue in 1966, predicted that production of a number of truck crops would be discontinued if harvesting and handling could not be mechanized. However, the University of California has been severely criticized and, in fact, is forced to defend a lawsuit based on replacement of farm labor because of development of tomato harvesting equipment. This was a case where industry did not conduct the research because possible profit from the limited number of such specialized machines required to serve the tomato industry did not appear to justify the research and development costs. The question again--Is saving an important industry for a state or region proper justification for the expenditure of public funds? It would seem that the answer should definitely be in the affirmative.

An example of where a mechanization effort failed is the okra harvesting machine in South Carolina, with the result that commercial okra production does not now exist in the state.

While the distinction between responsibilities of federal, state and industry research programs might be generalized to say that the federal establishment should attack those problems of national and regional interest, the SEAS should attack those of regional and local interest, and industry should handle those which have a profit generating motivation--or those problems which involve the production of new products or programs, and those which are necessary to establish the desirability, and safety of any types of products--the most important single factor really is communication to determine the nature of the problems and, for each participant to accept USDA, SAES, and industry responsibilities based upon the nature of the problems.

Limited markets or costs of federal or state regulation may make it impossible for industry to recover the costs it would incur in developing new products. The federal and state research agencies would definitely have a role in developing these products. A case in point is some of the more specialized pesticides where the costs of introduction are such that sales cannot possibly recover the cost of development, but yet these compounds are needed even in integrated pest management programs to effectively protect vital crops. The USDA and SAES certainly have a role in assisting to develop the necessary information on problems vital to the national economy, even though the impact may be local in nature.

A further area of support from agricultural research should be in the development and application of federal regulations. Where federal regulations need supportive research this should be accomplished by the federal research system.

Current program planning and budgetary procedures are described as an "adversary process" involving an annual justification for the support for--or existence of--research programs. The "adversaries" are the scientific staff and the administrative service personnel who have taken over much authority for program planning and budgeting. The national program staff are isolated from the research activities in the field and cannot be expected to have in-depth information from all components of their program areas. There are differences in the ability of the staff to fully comprehend and articulate the respective research programs, and it has been pointed out that as some of the senior and more experienced national program staff have retired, or departed, the programs under their general supervision have tended to atrophy. The ARS regional deputy administrators are too distant from the decision-making offices in Washington to be effective.

Of perhaps more significant importance is the need for stability in agricultural research, especially in the biological and physical sciences. Scientists cannot devote their full attention to research if they are continuously aware of the need for an annual justification of the existence of their programs. Also, it is becoming increasingly difficult to attract young scientists to positions with the ARS when they realize their tenure may be short-lived because of the vagaries of the present program planning and budgeting processes. It seems so obvious that the zero-based budgeting procedures are so ill-suited for agricultural research that corrective action should be taken promptly by appropriate officals of the government.

Another problem of concern to many is the perceived lack of connection between the planning and budgeting process. A plethora of planning occurs but when the USDA budget goes "behind the curtain" the planning appears to be ignored.

In referring to budgetary support for research, Pound (1979) states:

> "perhaps the greatest deficiency of our twin system is that the states are obligated to present their needs to congress through the Department's budget. The CR budget requests are hammered out in open association meetings with USDA being present and participating. The states are not allowed even a peek at the USDA budget requests. The states have generally had a free hand in making their requests, operating in recent years within the framework of a cooperative national planning effort. They have generally done poorly and tend to blame the USDA for not having national research coordination central to its mission. It is true that the USDA had defaulted terribly in this vein. In the early 1970's when NIH and NSF were retrenching with regard to agricultural research, agriculture was at sea in Washington without a captain. Secretaries Hardin, Butz and Bergland deserve very low grades for their leadership roles in support of agricultural research.
>
> "The significance of the present budget climate in Washington is the deteriorated support stance for agricultural research, particularly with the Executive Branch. It is my judgment that the Secretaries of Agriculture of recent years have defaulted badly in this regard. It must be recognized that a cabinet officer has to follow presidential policy but a strong and aggressive cabinet officer should be able to influence presidential policy."

It should be noted that the 1982 budget reflects a somewhat different stance on the part of the Executive.

It has been pointed out that prior to conversion to the present zero-based budgeting system those responsible for administration of agricultural research in the department--covering both USDA and SEA funds--looked upon research as an investment. The evidence of the returns on investments in agricultural research that has been recorded in the past two decades, from many programs in many countries, would certainly justify this concept in research planning and budgeting for the national agricultural research system of the U.S.

B. SAES

1. Serving Needs of Farmers and the Agricultural Sector of the State

As indicated earlier, the SAES in the beginning had essentially an exclusive focus on agricultural sector problems of the individual states. Regional and national responses were generated principally from the additive or replicative phenomena. There remains today a major element of those phenomena in the SAES programs and naturally so, given the heavy state funding relative to federal inputs. Considerably more coordination now occurs, however, due in large measure to enhanced communications and linkages developed over the years, both at the discipline and at the management and administrative levels.

The pressures to respond to in-state problems have resulted in heavy dominance of production and processing research in the SAES programs, with relatively less emphasis on natural resource conservation and community, environmental, and consumer-oriented activities, until very recent times. These same pressures have also resulted in a perhaps greater than optimal emphasis on applied as compared to more fundamental research.

But one cannot deny the productivity of those programs in solving agriculture's problems. As postulated by Evenson, et al., in a recent Science* article, one of the ingredients in this success has been the articulated character of the U.S. research establishment, in particular, the state element. The tight and continuous interactions between scientists, extension workers, and agricultural producers, processors, and marketers has been a constant force in keeping the facts of real life ever before the agricultural scientist. And, at the same time, the articulation in the science and education system itself has kept relevance high on the list and promoted the flow of basic science output to practice and the problems of practice to basic science.

Although the SAES retain their traditional focus in serving farmers and the agricultural sector of the state, their role is being modified substantially due to many factors, including:

a. Societal needs for the skills found concentrated in SAES (and USDA) increasingly transcend the needs of farmers and the agricultural sector. Examples include chemistry and metabolism of pesticides, and the use of soil descriptions in planning land use and in construction.

b. Limitations in funds available to the SAES from Hatch and state sources lead faculty to seek grant funds that may be available for nonagricultural topics. SAES directors have lost much of their control over programs because of outside funding.

c. Many new staff members do not have a background in farming and agriculture, and see more opportunity for recognition and rewards in research that is not closely identifiable with the needs of farmers.

Despite these strong countercurrents, the SAES work hard to maintain their identity with the farm community and to work with farm organizations. These organizations continue to be the strongest supporters of SAES.

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*SCIENCE 14 September 1979, Volume 205, pp. 1101-07

2. Changes in Cooperative National or Regional Programs

Formalization of the regional research authorization in the Research and Marketing Act of 1946 was an important factor in reshaping the SAES programs and, later, interactions with USDA efforts. It set in motion a program of regional projects that draw SAES scientists together to address their research efforts to common goals around regional and national problems. It has in recent years also drawn USDA scientists into those projects in an important way, thus serving as a Federal-State, as well as an interstate, coordinative device. But, it was not always so, as pointed out elsewhere. And it has, over time, been an important force behind the development of cooperative planning and implementation processes including the Regional and National Research Planning System, developed under the Agricultural Research Policy Advisory Committee and later the Joint Council on Food and Agricultural Sciences.

New cooperative programs frequently appear, and existing ones run their courses and are terminated. Current emphases in cooperative programs reflect increasing contemporary concerns with the environment.

3. Changes in Research Management

Federal requirements related to social objectives have increased the cost of research management and diverted managerial attention to concerns other than research objectives. The shift to competitive grants as a means of financing research has weakened and made more costly research management at the SAES due to several factors, including:

a. Priorities are frequently established nationally. This leaves little opportunity for the SAES director to guide a program that recognizes state and institutional priorities. Similar, duplicating programs in many stations have resulted from reaction to so-called national priorities.

b. Faculty members are encouraged to seek outside funding without primary consideration of state or institutional needs.

c. Decisions on funding are made without due regard to the total impact on resources and facilities by people who do not have to be accountable to legislative and agricultural interests.

d. Funding agencies are frequently unwilling to make long-term commitments.

C. Private Sector

1. Areas in which Agriculture is not Being Served Adequately

The Office of Management and Budget, with the concurrence of USDA Administration, has adopted a policy in recent years of determining which research programs should not be performed by public agencies. This has been done with little or no discussion with industry itself. The result is that certain areas of research have been neglected. The qualifications of OMB to make such a decision is obscure. There is no need for research administrators in the various governmental departments if the decisions on what to do are made by the staff of OMB.

The role of the participants in the national research system has been the subject of much discussion. Since industry management is responsible for the use of private funds in conducting their business, they cannot logically or legitimately spend these funds for problems other than those that affect their own industry. The concept of what affects that industry has been broadening in recent years, and it is now generally accepted that business does have a social responsibility for the types of products and services they develop.

The assumption by OMB of the authority to determine, unilaterally, what work should be undertaken by industry has resulted in less cooperation from industry and also in the omission of some necessary types of work from research programs. OMB is not qualified to make such judgments, and their judgments have very little effect on the types of work that industry undertakes. Thus, there are certain areas of work in which agriculture and the consuming public are not being served as they should. One of these areas is the post-harvest technology research program, because of lack of adequate funding determined jointly by both the OMB and USDA Administrators. First of all, there is very little information available on what the exact losses are in foods from the time of production to the time of consumption. GAO made one study of this problem and concluded that from 15 to 25 percent of different types of food are lost between harvesting and consumption. There have also been other attempts to evaluate these losses. Basically, one of the areas that has been neglected is an analysis of losses and identification of the sources of loss. This will very probably not be done by industry and the consumer will continue to pay for these losses.

In order to determine what areas of research would, in fact be picked up by industry if drastic cuts were made in Post Harvest Technology Research, the USDA awarded Contract No. 53-32R6-8-0005 to the Industrial Research Corporation, a subsidiary organization of the Industrial Research Institute, to make such an assessment. This study was in addition to an in-house evaluation of the problem conducted by the USDA staff in 1978. Approximately 60 agricultural industry companies which have research programs were interviewed by experienced research executives who had retired from industry. Two of the conclusions are particularly pertinent to this discussion:

a. Industry widely acclaims the importance of USDA performance of PHT research on practical objectives fulfilling human needs.

b. Possible termination or curtailment of PHT research by the USDA would have no significant effect on the kind and quantity of research performed by Agribusiness, as voiced in almost all cases (over 90%).

Thus, the conclusion is inescapable that the research programs in PHT conducted by USDA are not duplicative of work being carried on, nor would this work be picked up by industry. Therefore, the question is whether this work is justified. The report indicated strong support for the program.

The proposed reductions in the AR research budget in this area were largely restored by the Congress, but continued proposals for reductions have had devastating effects on the morale of the research workers in this field.

2. Restrictions on Federal Funds for Research on Mechanization

Another area in which agriculture is not being served results from the dictum from Secretary Bergland that "I will not put federal money into any project that results in saving of farm labor"--referring specifically to mechanization. Of course, the major part of the mechanization of agriculture has come from industry, as reviewed earlier in this report, and will continue to do so. Therefore, the policy of the Secretary would have resulted in further handicaps for the small industries concerned with developing farm machines since there is not enough return to justify the expenditure of their private funds for the development of more efficient equipment.

3. Constraints on Small Industries and Small Farms

The two policies mentioned here both lead toward concentration of research and development in the larger industrial corporations, and the small companies and small farms--which are supposed to be helped by present USDA policy--are left without the help they should have. Basically, then, there is a need for recognition that private industry does contribute a substantial amount to research and development of technology in this country. In fact, the survey by the Agricultural Research Institute in 1966 indicated that there are greater expenditures from the private sources than from public funding, particularly in agriculture. Secondly, there is need for greater interchange of ideas at the planning level, between the federal and state experiment stations and the industries, that will utilize promptly and effectively the results of research programs. There are attempts to move in this direction at the present time. But the first requisite of success in such a program will be to develop greater mutual respect and trust among the various segments of the research establishment.

In summary, the constraints appear to be problems of communication, of mutual respect, and the recognition that the solution of problems involving food and agriculture are of national importance and must be approached on a cooperative basis rather than on an adversary basis.

V. REALIGNMENTS IN THE NATIONAL RESEARCH SYSTEM

A. Assessment of the Historical Base

1. Federal Support for Agricultural Research and Development

Review of the actions, and concerns, by agricultural leaders and the Congress from early colonial times until 1862 indicates clearly the deep concern on the part of federal government leaders about furnishing federal funding for agricultural development. This was based in part on the question of constitutionality of such support as well as the fear that federal funding for agriculture would "serve political purposes." The position of the Congress held firm in spite of strong presentations from individual agricultural leaders and the various associations formed to foster improvement of agriculture.

The breakthrough in 1862 is of special interest since during this year--in the midst of the Civil War--Acts were passed by the Congress establishing the U.S. Department of Agriculture and providing for federal land grants for establishing colleges of agriculture in the states and territories, as well as the passage of the Homestead Act. These legislative actions not only served to recognize federal responsibility for fostering agricultural development but also identified a federal role and a state role in these endeavors. The Hatch Acts of 1887 furnishing funds for the development of experimental capabilities at the state level and of 1889 providing cabinet rank for the Department of Agriculture reflected the intent of the Congress at that time that the federal government as well as the states should have strong capabilities for agricultural research and development.

Subsequent legislation, including (but not limited to) the Purnell Act of 1925, the Bankhead-Jones Act of 1935, and the Research and Marketing Act of 1946, similarly recognized the mutual responsibilities of the USDA and the states.

It was intended that the USDA and the states would work together through (a) an Office of Experiment Stations in the Department of Agriculture, (b) an Association of Aricultural Colleges and Experiment Stations, (c) the Association of Official Agricultural Chemists, and (d) the Association for the Promotion of Agricultural Science. These organizations did not impede the autonomy of the work of the USDA and the SAES but did furnish forums for activities of mutual interest.

Federal funding for agricultural research--and for the related fields of education and extension--was strongly disciplined from colonial days through the first half of the twentieth century, essentially until about 1960. The U.S. reaction to the Russian launching of Sputnik caused widespread concern that science and technology in this country was falling behind that of the Russians. The pressure from the U.S. scientific community, especially emphasizing the need for greater basic research in the U.S., caused the Congress to furnish--promptly and rather lavishly--funds for the support of basic research through the National Science Foundation, the Atomic Energy Commission, the National Aeronautics and Space Administration, the National Institutes of Health, and other organizations. Such funds, over and above the expanded research and development funding within the Department of Defense, were to be utilized largely as grants to individuals or to groups of persons to pursue selected "basic or fundamental" studies designed to broaden the base of understanding of a wide range of biological and physical phenomena.

The grant funds were not restricted to use by physicists and engineers. They were attractive resources for research and teaching staff members of land grant universities and other educational institutions. They were not available to scientists of the USDA. The freely available "soft monies" through project grants over the past 20 years, initially for largely military-related research but subsequently expanded in the Department of Health, Education and Welfare, the U.S. Department of Agriculture, and the U.S. Agency for International Development, furnished a substantial reservoir for individual scientists. This not only fostered a broadened base of involvement of individuals in the U.S. scientific community, it also seriously affected the institutional structure, discipline, and orderliness of research prioritization and direction. This was particularly true in the state agricultural experiment stations and the land grant universities, where individual staff members could go their own way, concentrating on research where the money was, rather than directing their efforts to the more critical needs and concerns of farmers and others in the agricultural industries of their states.

The changing pattern of federal support for agricultural research, especially as this has evolved in the past 20 years, is critical to the present study. The era of pluralism in research, providing for participation by many scientists (and also many with limited interest in and capability for research), has positive and negative features. The Congress is very much concerned about wastage of grant funds, as indicated by the extensive hearings initiated as early as 1963 by Representative Howard Smith of Virginia, Chairman of the House Rules Committee. This concern became prevalent throughout the Congress and has had a continuing impact on the nature and magnitude of federal support for research in the succeeding years.

The change from the past emphasis on well-defined, directed, mission-oriented research--subject to close scrutiny by the Congress--to the recent free flow of blocks of funds for support of a wide range of studies undertaken by individuals, with limited accountability to the institutional leadership or to the federal agencies through which the grant funds are channeled, is a factor in the definition of the roles of the USDA, SAES, and private sector in agricultural research.

2. Evolution of the USDA-SAES Relationships

There are limited records with respect to cooperation between the USDA and the research workers in the state institutions prior to the Congressional action of 1862 establishing the Department of Agriculture and providing the land grants for colleges in the states and territories. However, there were varying degrees of cooperation on problems of mutual interest prior to 1900. The strengthening of the institutional structure of USDA research through setting up the subject matter bureaus after 1900, together with the strengthening of state experiment station capabilities through the Hatch Act of 1877 and subsequent legislation, were factors in formalizing the cooperative relationships.

The development of coordinated regional and national programs, beginning with the work of the Office of Dry Land Agriculture in 1906, which was complemented by the cooperative work on forage and cereal crop improvement, further formalized the working relationships. It is of interest that this cooperation represented a joint initiative and mutual interest on the part of research workers in both the USDA and the SAES. This holds true for the subsequent development of national and regional coordinated research for crop improvement, initially for the hard red winter wheat improvement program in the Great Plains, the corn improvement research in the corn belt (and later in the southern states), soybean research, and the crop production practices in the southern states and many other areas.

These relationships were built on the mutual respect and recognition that initiatives could come from either the USDA or the SAES participants. They recognized that certain components of the cooperative programs were of regional or national concern, while other aspects of the problems were primarily of state or local interest. There was a respect for and appreciation of the role of the investigations leaders of the USDA who carried on research and not only furnished conceptual inputs, information exchange, and coordinating services, but also promptly summarized and reported the results of the cooperative work on a schedule that facilitated annual review and planning for the coming crop season. And there was equal respect and recognition for SAES personnel who furnished critical inputs into the team research.

The collaborative relationships were not limited to the top echelons of leadership in the USDA and their counterparts in the SAES. The heads of the departments and individual scientists in the SAES maintained effective working relationships with the heads of the divisions of the USDA research bureaus, the investigations leaders, and the federal research personnel, many of whom were located at cooperating state agricultural experiment stations.

The advent of the Research and Marketing Act of 1946, as discussed previously, had the effect of strengthening the interaction between the state agricultural experiment stations in addressing problems of mutual concern on a "regional" basis. But there was also a lessening of the interaction of the USDA and SAES as the state experiment stations exercised greater independence in planning and executing these regional activities. However, there was still a substantial cooperative relationship based on the maintenance of the structure of the coordinated regional and national programs and the personal and professional relationships of scientists in the USDA and the SAES. This was disrupted somewhat by the reorganization of the USDA research in 1953, but much of the cooperation persisted through the new linkages developed with the USDA branches, and through maintenance of the roles of the investigations leaders and other participants in the respective cooperative research programs.

Perhaps the most significant and serious impact on the USDA/SAES relationships have resulted from the events of the past 20 years, particularly the reviews of the national agricultural research capabilities by the PSAC Agricultural Panel in 1962 and the NAS Committee in 1972. These reviews, undertaken largely by SAES or university personnel, represent a situation in which one partner undertook assessment of the total organization in which it has a strong vested interest with respect to funding, facilities, organization, and operations.

The advent of the abundant monies in federal agencies for grants to individual scientists or groups of researchers led to substantial diversion of interests of research workers, primarily in the SAES and universities since the USDA and other federal agencies were generally not eligible for such funds. This has had a significant influence on the institutional structure and line authority of the directors of the experiment stations, heads of departments, and others responsible for the total research, education, and extension programs in the universities.

There are divergent views with respect to the continuing emphasis by some scientists on the deficiency in basic research--a theme perpetuated since the post-Sputnik era of the late 1950's. As viewed by Pound (1979), "during the late 1950's and during the decade of the 60's, agricultural and agriculturally related research profited very greatly from support from federal granting agencies, particularly NSF and NIH. As federal resources became tighter toward the end of the 60's, however, these funding agencies reduced support and the agricultural research establishment found itself with, what some observers viewed, a threatened future. Of particular concern to some, but by no means all, was the evidence accumulating that agricultural productivity was plateauing, primarily because of a slowdown in the generation of information technology; that inputs into basic research from which production technology would flow were inadequate."

The diversity of judgments of individuals with respect to the deterioration of basic research and its impact on agriculture was touched upon by Dr. Sterling B. Hendricks in discussing research in photosynthesis (ANNEX II). Hendricks stated that it was doubtful that knowledge of photosynthesis had really been useful in agriculture to that date (1972), although it may be in the future. The question which the NAS Committee neglected, in his view, was whether the basic research of the ARS was good for agriculture, not whether it satisfied academic criteria such as publications lists. Some ARS officials (ANNEX II) tended to distinguish between basic research and what they called academic research. According to their views "scientists at Harvard and Yale have spent thousands of dollars from the NSF on photosynthesis research, none of which could be translated into more efficient crop production; nor is there much point in sending ARS scientists to international congresses where such results are discussed because the same kinds of things are being said there now (1973) as were said twenty years ago."

There is a general acceptance of the value of having a broad involvement of individual scientists in the total national agricultural research system. However, the advent of expansive research grants to individuals has created a substantial degree of disorder in what should be--in science--a reasonable degree of order and self-discipline. Agricultural research in the U.S. has been criticized in the past decade or more for a lack of focus or direction, a lack of commitment to the solving of problems or removing constraints in agriculture, and the lack of a sense of urgency. There also is the criticism of a lack of leadership and direction, levelled equally at the USDA and the SAES. The reduced pressure on agricultural research since the end of World War II, and the Korean War in the early 1950s, has tended to reduce the sense of urgency, although this is less a reduction than a redirection in view of current concerns with environmental problems, resource conservation and use, and varied consumer interests.

The impact of the pluralism or individualism in research has undoubtedly been greater in the SAES--where the staff members have had access to project grants--than it has been in the USDA. However, the combination of the project grants as they effect the SAES, together with the reorganization of 1972 as it effects the USDA, combine to complicate the line authorities and research direction and management--with the resultant increasing difficulty in maintaining the close collaborative USDA-SAES relationship that previously prevailed.

Pound (1979), in assessing programming procedures and relations between the USDA and SAES, states "the Bankhead-Jones Act and its amendment of 1946 established a statutory mechanism of cooperative programming among the states and the USDA. From these laws and from experiences in administering them have come a comprehensive, complex, bureaucratic system of joint planning.

"The objectives of regional research and marketing research were laudatory in trying to reduce excessive duplication, to provide coordinated attacks on regional problems, and to enhance communications between the scientists. But we have not met these objectives well, except for better communication and that we have done to a point of fault.

"We go through an elaborate process of national program planning but have no mechanism of follow through. Administrative costs of regional research are excessive because responsibility, being divided between 12 or more states, CR, and as many subject matter departments, is too diffuse and procedures are too democratic. The paperwork attached to regional research is much too great. Our regional research format should be abandoned.

"Title III of the Bankhead-Jones amendment (the Research and Marketing Act of 1946) called for the establishment of a national advisory committee to assist in the establishing of research priorities and as a general 'PR' committee. This was the beginning of a committee bureaucracy syndrome, created by legislative action, that had little authority and did little good. The advisory committee structures created by Title V (Rural Development Act of 1972), Title XII (Freedom from Hunger Act of 1977), and Title XIV (Agricultural Research, Extension, and Teaching Act) are excellent examples of uncontrollable costs of social governance that contribute little, if anything, of value to the agricultural research establishment.

"The Hatch Act amendments of 1955 required that 25% of the formula funds be devoted to regional research and that another 20% be used for marketing research. These requirements force a bureaucracy of administration that has resulted in an inefficient use of research money in too many cases."

Castle (1980) states, "Federalism is undergoing constant evaluation on many fronts but the unique historic relationship between the USDA and the Lant Grant Universities has evolved into a set of institutional relations that are unrivaled in complexity. The question should be faced squarely as to whether the historic partnership between the USDA and the Land Grant Universities remains viable. The Food and Agriculture Act of 1977, the numerous constituencies that must be served by USDA, together with the multiple ties between higher education and the federal government, raise questions as to whether the partners still are marching to the same drummer. What happens during the next four years probably will decide whether the point of no return on the road to dissolution of the partnership has been passed, or whether recent events will be viewed only as a series of family spats, not unlike a political party's national convention--a necessary prelude to battle against a common enemy.

"Embedded in this federal-state issue are the inherent stresses within the two partners. The organization of the Science and Education Administration brought many of the internal USDA tensions into the open. But of equal or of greater significance are the conflicts that exist within the 1862 Land Grant Universities. I will be more specific.

"The Land Grant Universities, through necessity, have created elaborate organizations to administer their research, teaching, and extension programs in agriculture. These organizational arrangements are by no means uniform; numerous permutations and combinations exist. But four major concentrations of power can be identified that have resulted from increased size and the separation of functions--the university president, the vice president or dean of agriculture, the Experiment Station director, and the director of Cooperative Extension. The planning framework which has been advanced by the Joint Council has not only brought federal-state conflicts to the surface but it has also intensified internal Land Grant University tensions and these tensions now are being reflected at regional and national levels. To be specific, the regional coordination of extension, teaching, and research may mean that Experiment

Station and/or Extension directors will have to subject their regional plans to a regional committee of deans or vice presidents. The result is what may seem to be a significant loss of autonomy for directors who are accustomed to advancing their regional plans on the national level.

"Of course, conflicts between and among these sources of power are not new and have often been manifested on the national level. But what is new is the way the planning mechanism being put in place by the Joint Council has intertwined these conflicts with those between the states and the federal government.

"The identification of these four major sources of tension does not exhaust the list which could be compiled. Nevertheless, their identification defines the major problems facing agricultural administrators and leads to a fundamental question.

"Is the system now so constrained that there is little or no room for creative decision making? Is it to be compared to an over-determined set of equations, to use a mathematical analogy, or to the absence of degrees of freedom, to use a statistical parallel? Or, do these manifold tensions and processes provide an opportunity for creative administration and innovative leadership?"

B. Functions of the National Research System

1. Scope as Defined in the Food and Agricultural Act of 1977

In the April issue of California Agriculture James B. Kendrick, Jr., Vice President for Agriculture of the University of California system contributed an editorial entitled "Clearing Away Confusion About Agricultural Research." He stated, "Agriculture has changed dramatically in the past twenty-five years; the basic mission of agricultural research has not. Our fundamental purpose remains to improve productive efficiency on our farms, to conserve our resources, and to protect the environment, in the interests of all citizens." He further stated, "We in publicly supported research institutions need to keep our aim on the total public benefit. We should be dedicated not only to the adequacy of our country's food and fiber supplies but also to the well-being of the environment and social structure in which they are produced."

The diversity of interest involved in food and agricultural research, and the multiplicity of disciplines contributing to research in those fields is often not recognized. The Science and Education Administration of the U.S. Department of Agriculture has accepted the definition used by the Congress in the bill passed in 1977 under Title XIV of Public Law 95-113. This definition is: "The term 'food and agricultural sciences' means sciences related to food and agriculture in the broadest sense, including the social, economic and political considerations of:

a. Agriculture, including soil and water conservation and use, the use of organic waste materials to improve soil tilth and fertility, plant and animal production and protection, and plant and animal health;

b. The processing, distributing, marketing, and utilization of foods and agricultural products;

c. Forestry, including range management, production of forest and range products, multiple use of forest and range lands, and urban forestry;

d. Aquaculture;

e. Home economics, human nutrition, and family life; and

f. Rural and community development."

This definition illustrates very well the complexity and broad scope of problems which must be addressed in food and agricultural research. This is further complicated by the fact that research programs must take into account the problems of export of agricultural and food products, and also some of the problems that are concerned with U.S. aid to developing countries.

As stated in the NAS Committee Report of April 1972, "It has become increasingly difficult to distinguish between agricultural and non-agricultural research, and agricultural research cannot be restricted to empirical comparisons of methods to increase productivity. The practice of agriculture has long outgrown the individual farmer and his art. It is now an industry with the diversity, complexity, and size characteristic of industry as a whole. It requires research, policy and programs sufficient to challenge the best efforts and minds of America. And on its success depends in large part the welfare of the people of the United States and of the world. It must be given the attention, careful and imaginative planning, and best judgment of the government and of scientists."

The Science and Education Administration of the USDA, in the recent publication (September 1980) "The Mission of the Science and Education Administration--Agricultural Research," outlines the mission and goals, the role and special capability of SEA/AR, the organization and functions, and a description of a wide range of research programs. The publication also includes an excellent compilation of the statutes relating to the agricultural research activities of the SEA.

The foregoing statements and documents identify the scope and complexity of the agricultural sector and the research required to serve it. The SEA publication of September 1980, pages 6 and 7, describes (a) the SEA/AR responsibilities for the national program, (b) the partnership with the state agricultural experiment stations, and (c) the association with industry. The SEA document provides a good framework for the assessment of the national research system. The critical questions however are whether the system is functioning as the SEA paper purports; whether the responsibilities of the USDA, SAES, and the private sector are as clearly defined as indicated; whether the relationships are actually as stated; and whether the organization, operations, and leadership are of the nature and caliber to make the system work.

2. National and Regional Programs

The USDA-SEA report "The Mission of Science and Education Administration--Agricultural Research" furnishes the following guidance with respect to national and regional programs:

a. As the U.S. Department of Agriculture's in-house agricultural research unit, SEA/AR has major responsibilities for conducting and leading the national agricultural research effort.

b. The state agricultural experiment stations, with mainly local and regional interests, work in cooperation with SEA/AR and contribute to national and broad regional research efforts.

The foregoing are the long-standing definitions of the respective USDA and SAES primary responsibilities and areas of concern. However, it is because of the blurring of these national and regional generalized responsibilities that the partnership has become somewhat confused, and funding at the federal level for the principle public sector partners has been increasingly uncertain in the last decade or more.

While this publication provides an excellent general statement of the objectives of in house research programs of SEA/AR it is only a general statement, and will provide very little guidance for anyone trying to define the role of the SEA/AR compared to that of the SAES or industry. The questions of specifically what does SEA/AR do that is not done by other organizations, and how does SEA/AR differentiate its responsibilities from those of other departments within the government, SAES and the private sector remain vague and not defined. This is not surprising, because there is no way to define rigid areas of responsibility which would fit in a multitude of cases. Clear definition carries with it the obvious undesirability of rigidity and lack of opportunity to evaluate the need for differences in approach to different problems in differing circumstances.

The statement that it is the responsibility of agricultural research in SEA/AR to address problems of national or regional interest is not clearly definitive but as a general classification is probably as satisfactory as any. This is not a rigid dividing line and should not be. There are instances where federal, state, and industry all may attack problems of national and regional interest when these are of mutual concern.

The reorganizations of 1972 and 1977 appear to have moved away from this concept. The reorganizational emphasis was placed upon detailed contacts down to the local level, as exemplified by the area director concept. This would seem to indicate an increasing interest in local issues on the part of SEA/AR, rather than concentrating on national and regional problems, and on the development of national programs and leaders.

The reviews and reorganizations of agricultural research in the past 20 years have been given special attention in this paper because they have been a key factor in keeping the national and regional activities of the USDA and the SAES in a continuously disruptive and unsettled state. This is reflected not only in the current lack of definition of the role of the USDA in conceptual, operational, and coordinating leadership in national programs, but also in the manner in which USDA financial and staff resources are applied and utilized in the national research system.

It is necessary to adapt and adjust the national research capabilities to meet continually changing requirements of those served by agricultural research. This has been particularly critical in the past few decades as the continuing needs of farmers for improved technology were joined by the new and increasingly persistent demands of other sectors of society for answers to problems related to the environment and consumer interests.

Constraints to the effective functioning of national and regional programs have been discussed in some detail in this paper. They reflect the combination of (a) the USDA research organization, (b) the structural and scientific capability constraints to national and regional program leadership, (c) the lack of clear definition of national and regional program objectives, and (d) a need for clarification of the respective roles of research program management and those who are concerned with administrative functions (which in a research organization should be concerned with servicing research rather than controlling it).

3. International Programs

The USDA has a long history of international cooperation, from the early introduction and exchange of plant and animal germ plasm materials, through the cooperative studies of plant and animal pests and diseases, the introduction of insect predators, and insects and diseases to control introduced weeds. USDA scientists have been located overseas to conduct research on exotic diseases and pests, such as the African swine fever, the Mexican fruit fly, the Mediterranean and oriental fruit flies, and many others.

The work of USDA scientists in formulating and advising on research in foreign countries, supported with Public Law 480 funds, has contributed significantly to U.S. agriculture and also the advancement of agriculture abroad, particularly in developing nations. The USDA also has cooperated for many years with the USAID in crop and livestock improvement, the control of the tsetse fly and other insect pests and diseases of crops and livestock, in soil and water management, and in joint projects involving the international agricultural research centers. The USDA also has an active program in the training of foreign agricultural scientists and specialists.

It is difficult to assess the relative benefits to the U.S. and to foreign countries but, on the basis of the types and extent of research projects, it is safe to assume that there has been a substantial contribution to both domestic and foreign agricultural development as the result of such cooperation. The USDA, through the years, has recognized and respected the charter of USAID and its predecessor agencies with respect to foreign aid programs. In fact, the USDA was subject to some criticism during the first fifteen years or more of foreign aid activities--through the mid 1960s--for its limited involvement in foreign aid work. This reflected the conviction of the research administrator, Dr. Byron T. Shaw, that the USDA was established to serve American agriculture and, therefore, its staff and other resources should not be diverted unduly to foreign aid activities.

The SAES also have collaborated in a wide range of international agricultural activities, dating back to the cooperation of the Massachusetts Agricultural College in assisting in the establishment of the College of Agriculture in Hokkaido, Japan, in the latter part of the 19th century, and many similar ventures since that time.

Since the initiation of the Point IV program in the early 1950s the U.S. land grant colleges and universities have had an active role in foreign aid programs. Significant contributions have been made, particularly in the development of colleges of agriculture or agricultural universities in the Philippines, India, Brazil, and any number of other developing nations.

Unlike the USDA, which has been subject to criticism for a lack of initiative in participating in foreign aid programs, many of the land grant universities have moved rather vigorously in cooperative work in developing nations. In most instances this has involved the educational component of the land grant institutions, rather than the experiment station staff. The emphasis was, initially, on setting up the teaching and training functions of the agricultural universities or colleges of agriculture abroad. In many cases there has been limited attention--almost inadequate attention--to the research arm of the institutions.

The relationships between the SAES or the land grant universities and the USAID were discussed earlier in this paper. The increasingly prominent role of the universities, particularly as exemplified by the establishment of Title XII, may have had some deleterious effect on USAID through constraints on employment of direct-hire staff by USAID for the essential long-term assignments in the field missions. Advancement of agriculture through the generation and use of improved technology requires a long-range, sustained effort. This was true in the United States and is equally true in the developing nations. Limited progress will be made if this job is approached on a short-term, piece-meal, and hit-and-run basis.

It is recognized increasingly that the individual--and somewhat isolated--project approach is not particularly useful in foreign aid programs. Without an effective institutional structure in the developing countries such projects make little impact and have a short life span. Greater emphasis must be placed, therefore, on the building of the institutional capabilities in the developing nations for the generation of improved technology, the verification of such innovations, the farm-field testing for adaptation, and the ensured application and use by farmers. The latter requires attention not only to "extension" but the provision of various inputs and services necessary for a viable and continuously growing agriculture. In this context, it is essential that there be an agency representing the U.S. in the foreign aid field that has the recognition, capability, priority commitment, and continuity necessary to do the job. The work cannot be done on a competitive grants or isolated projects approach. Also, it is well appreciated that the U.S. institutional structure cannot be transplanted more or less intact into the institutional arrangements and social and economic structures of developing nations. This was learned with respect to extension during the first 15 years of our foreign aid activities. The triumverate of teaching, research, and extension in institutions established in most foreign countries has limited usefulness where education is under a ministry of education, agricultural research and development are under a ministry of agriculture, and extension activities may be under the ministry of rural development or another body in the national government. The U.S. experience is relevant primarily in recognizing the functions of our national agricultural research and development system, and fitting these functions into an integrated pattern within the institutional structure of developing nations.

It is important that the USDA, the SAES, and--increasingly--the private sector of U.S. agriculture become more effectively involved in the foreign aid program. This does not mean more heavily involved, but rather a more selective participation in a fully cooperative way, with the recognition that the USAID has a special national role in carrying out the U.S. responsibilities. This will require a willingness to recognize the priority or primary responsibilities of the federal, state, and private sector in cooperative efforts.

4. Future Emphases -- Resource Conservation and Use, Environmental Problems, and Consumer Interests

We are acutely aware that "agriculture has changed dramatically in the past 25 years but the basic mission of agricultural research has not." This is reflected by the shifts in emphasis in crop improvement, from the public sector to the private sector, for many of the major crops. And also in the emerging increased concerns for resource use and conservation, environmental problems, and various consumer interests.

The references earlier in this paper to the role of federal investigations leaders were focussed largely on the regional or geographic area projects concerned with dry land farming, wheat improvement, corn and soybean improvement, and similar programs characteristic of the early stages of a modernizing agriculture. The national and regional functions of the USDA, the priority concerns of the SAES with problems of local and state-wide interests, and the interlacing relationships of the private sector had substantial meaning so long as the respective participants in the national research system were willing to recognize and broadly differentiate their roles in these categories.

Bertrand (1980) identifies problems confronting agriculture on a world-wide basis to the year 2000, and also some specific factors of domestic concern--subject to resolution at least in part through a stronger national research program. Bertrand's list includes the following:

a. Domestic demographics--including population growth, age mix, urban-rural migration, geographic shifts of population, and ethnic group changes.

b. Our agricultural production capacity--for crops and animal productivity, with attention to energy needs, efficiencies or costs of production, and nutritional requirements.

c. Pest management--with the dimensions of effective controls, environmental impacts, and human health hazards (assessed economically in total public interest).

d. Post-harvest factors--of processing, marketing, utilization, and consumption.

e. Ecological concerns--covering the broad spectrum of energy supplies and environmental inpacts, water supplies and use, water and air pollution, and many agriculturally-based thrusts in the energy scene of the future.

f. Clientele concerns--covering a range of issues, including research to guide impacts of new technology such as research to back up action and regulatory agencies and for monitoring quality and safety of foods.

g. Basic research--an area that requires continued support (and balance with continued problem-solving research of direct benefit to the public that supports research).

Castle (1980), in considering the changing challenges to research and education in the future, recognizes the diverse needs and demands of the multiple clientele. He says:

> "Even if the popular function of the university were embraced wholeheartedly there would still be a major problem of balancing the response among clientele groups. How are the interests of the urban gardener to be weighed against the needs of the farmer who grosses over $1 million per year? To what extent should the problems of farming be emphasized relative to the problem of the rural community? How do the issues of consumerism get balanced against the requirements for production? Should those who are affected by stream siltation and the escape of agricultural chemicals from the farm be considered in the design of agricultural research and extension programs?
>
> "There is no problem more important to the administrator of agricultural education and research programs than the reconciliation of the interests of multiple clientele."

The current interests and/or constraints confronting the agricultural sector tend to differ substantially in substance from the problems of earlier decades. But the form and philosophy of the research approach--or system--in tackling these problems can very well follow the pattern of shared responsibilities that has characterized the coordinated, cooperative national and regional research throughout most of the system's history. A basic requirement is that the participants exercise the willingness to defend and recognize the role of the cooperating institutions and carry out the cooperative programs accordingly.

Most of the major concerns confronting agricultural scientists today are of national or regional scope. They are no more restricted to state boundaries or to regional organization boundaries than was hog cholera restricted to the boundaries of the state of Missouri. It would seem reasonable to have a kind of cooperative endeavor in which the SAES scientists focus most intensively on problems within the respective states, or subregions, in which USDA scientists give special attention to those kinds of problems that transcend state boundaries, and that close cooperation prevail as determined by (a) mutuality of concern about the problems, (b) the most effective use of scientific capabilities and other research resources, and (c) the mutual understanding that someone has to be in charge or responsible.

The nature of the problems confronting the agricultural science community in 1980 are more complex and as urgent as any sets of problems in the past. There is need for a sense of urgency in resolving them. There is need for at least as much concern for satisfying the total needs and requirements of society as for satisfying the wishes and desires of individual scientists. The question of the lack of a sense of urgency, and the lack of leadership and direction in meeting problems of national concern, has been raised more frequently than any other issue among persons contacted on the subject of this paper. Today's problems require the best efforts of our national research system.

5. Financial Support

Paarlberg (1980), in assessing the changing scene for agricultural research in the future, states:

> "the agricultural setting which Dr. Bertrand describes calls for changing emphasis in research. Some priorities must be lifted up. Requests for across-the-board increases for each of the disciplines will not be convincing to the appropriations committees. In fact, this is what has turned them off in the past. Across-the-board requests for increased funds appear to the appropriations committees more as a defense of the research bureaucracy than as an earnest effort to solve the problems of agriculture. How are priorities to be determined? Who will tell the researchers in the disfavored disciplines that their work is to be de-emphasized? The credibility of the research effort can be established only if leadership will assume these difficult tasks.
>
> "There has been a transformation on the funding of agricultural research. Ruttan shows that, since 1960, Federal Formula (Hatch) support for the State Agricultural Experiment Stations has been virtually stagnant at about 50 million 1967 dollars. Meanwhile, total federal appropriations for agricultural research, including federal agencies such as the National Institutes of Health, National Science Foundation, and the Environmental Projection Agency, have risen from about 150 to 250 million dollars, also in 1967 terms. Appropriations for agricultural research, administered through these agencies, now exceed the federal funds available to the State Experiment Stations by a factor of five.
>
> "What are the reasons for this shift? Why are the new increments of federal funding going to these new agencies? Modern agricultural research tends to be mission oriented and multidisciplinary, involving the commitment of very large sums over long periods of time. The discovery of new knowledge doesn't come easily, in small packages suited to the granting of a Ph.D. in a particular discipline, as it once did. To the Land Grant Colleges, geared as they long have been to the development of agricultural scientists, this is a disquieting fact. They have not organized themselves to combine well in a modern setting the two functions of developing agricultural scientists and discovering new knowledge. It may be that to obtain increased Federal support for the Experiment Stations, something more is required than a greater lobbying effort. Research methods may need review. In my field, agricultural economics, our models sometimes increase in rigor while they decrease in predictive ability. These problems are complicated by the current mood to restrain federal expenditures."

ACRONYMS

AEC	Atomic Energy Commission
AR	Agricultural Research (of SEA)
ARA	Agricultural Research Administration (1941-1953)
ARS	Agricultural Research Service (1953-1977)
BAI	Bureau of Animal Industry
BAIC	Bureau of Agricultural and Industrial Chemistry
BDI	Bureau of Dairy Industry
BEPQ	Bureau of Entomology and Plant Quarantine
BHNHE	Bureau of Human Nutrition and Home Economics
BPISAE	Bureau of Plant Industry, Soils, and Agricultural Engineering
CAS	Committee on Agricultural Science (1963-1969)
CR	Cooperative Research (of SEA)
CSESS	Cooperative State Experiment Station Service
CSRS	Cooperative State Research Service
FDA	Food and Drug Administration
HEW	Department of Health, Education, and Welfare
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NIH	National Institutes of Health
NPS	National Program Staff of SEA/AR
NSF	National Sciences Foundation
OES	Office of Experiment Stations
PSAC	President's Science Advisory Committee
RMA	Research and Marketing Act of 1946
SAES	State Agricultural Experiment Stations
SEA	Science and Education Administration
UAB	Users Advisory Board
USDA	United States Department of Agriculture

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SCIENCE

News and Comment

AGRICULTURE: NAS PANEL CHARGES INEPT MANAGEMENT, POOR RESEARCH*

A candid and remarkably critical survey of agricultural research conducted at both the federal and state level has been prepared by a committee convened by the National Academy of Sciences. Administrators at the U.S. Department of Agriculture (USDA) appear to accept many of the criticisms but say that most of the necessary reforms are already in hand.

The survey faults the quality of agricultural research right across the board, ranging from poor administrative leadership in the USDA, to misallocation of resources for research, neglect of basic sciences, and the low quality of science and scientists both in the USDA and at state supported research institutes. It is the work of a 19-man committee chaired by Glenn S. Pound, dean of the College of Agriculture and Life Sciences at the Univeristy of Wisconsin. The committee, which consisted mostly of university scientists, included as members Nyle C. Brady, a former director of science and education at the USDA, and Nobel prize winner Robert W. Holley. It was set up in the summer of 1969 at the request of the then Secretary of Agriculture, Clifford M. Hardin, who wanted the quality of agricultural research to be assessed by an outside group. A report was submitted to the USDA in 1972 and will be published early this year by the National Technical Information Service.*

The study consists of a main section, comprising 20 specific recommendations for reform, and a number of appendices covering the topics investigated by special subcommittees. The appendices will be discussed in a later article. What follows is a resume of the main report and the USDA's reaction to it.

The subject matter of the NAS study is a research enterprise that costs about half a billion dollars annually and commands the services of some 10,500 scientists in more than 500 laboratories. More than half of this is spent by the USDA on in-house research through its Agricultural Research Service, Forest Service, and other programs; the rest is supplied by states, the USDA, and other federal agencies to support research at the State Agricultural Experimental Stations (SAES). Although this research comprises a smallish fraction of national R & D expenditures, it amounts to nearly a quarter of the total budget of the National Institute of Health and represents a substantial fraction of government funds available for biological research.

The NAS committee states in summary that it has found many excellent programs, well-trained scientists, and sensible research management in the USDA and SAES. But there is also reason to believe that "much of agricultural research is outmoded, pedestrian, and inefficient." The committee found evidence, the summary continues, "that in the allocation of resources for agricultural research, grossly inadequate support was given to the basic sciences that underpin agriculture; that the agricultural research establishment seems to have an excessive number of field laboratories with an undesirably low level of coordination and integration of SAES-USDA efforts; that disproportionate commitment of funds to some areas has resulted in...weakening the vitality and balance of the total program.

"Evidence was also found that in the research itself there is an unwarranted duplication of effort...;that far too much of the research is of low scientific quality, indicating low ability of some researchers or poor administrative management of the researcher.

"In the area of management of scientists, the committee found very disturbing evidence of ineptness with direct impact on research quality. Administrative structures and philosophies were found that reduce the decision-making power and freedom of movement

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*Report of the Committee on Research Advisory to the USDA. National Technical Information Service, Springfield, Va., 464 pp.

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of the scientists, with repressive effects on the vitality of science. Programs of staff improvement, throughout the system, are either grossly inadequate, or ineffectively used, resulting in stagnation and premature obsolescence of the scientists."

The NAS committee arrived at this blunt conclusion by addressing itself to several basic questions about the nature of agricultural research. The key question, "Does the research by agricultural scientists reflect the highest standards of the scientific community?" receives perhaps the directest answer of all: "Most of the specific disciplinary research studies made by the committee and its panels reveal a shocking amount of low quality research in agriculture. Admittedly, quality is a judgment factor, but the regularity with which the committee came up with judgments of low quality, including both USDA and SAES research, is significant and appalling."

The conclusion rests in part on an evaluation of USDA and SAES research projects in selected areas such as reproductive physiology, in which 42 percent were rated by panel scientists as "poor," and molecular biology, in which only 8 percent were judged good enough to receive support from the NIH or National Science Foundation. The committee reviewed 225 projects in reproductive physiology and found that 43 dealt with repetitive studies of hormone secretion. Members were convinced that there is "an inexcusable amount of mediocre and duplicative research and that the element of directed research is too great."

The underlying cause of this failing, the committee clearly believes, is the lack of proper review by competent scientists, such as the peer review system operated by agencies such as the NIH and NSF. A similar review procedure, drawing upon scientists in universities, industry, and other agencies, should be instituted by USDA and SAES, the committee recommends.

Management of Research

How did standards sink to such apparent depths? One factor identified by the NAS study is poor research management, including heavy-handed administration which has both overdirected research and stifled creativity with a welter of bureaucratic impediments. The agricultural research establishment has an undesirable burden of administrative and planning effort that, in effect, is removing the active researcher from decision-making. Agriculture has had a "plethora of planning" over the last decade--the burden of bureaucracy becoming increasingly burdensome with each succeeding reorganization--yet "little has resulted from much of the planning other than to create additional layers of administration at the expense of program." Specifically, the NAS committee "feels that the USDA has some problems in removing unsatisfactory administrators."

In this atmosphere, the research environment of USDA is losing its attractiveness. "Unless extreme care is exercised, there is great risk of suppressing the individual freedom of the scientist and of accepting objectives of lower scientific integrity." The remedies, as the committee sees it, are to give active researchers a larger say in decision-making, to weed out the bad administrators, and to recruit from outside the USDA as well as internally so as to get the best scientists available.

Another failure of agricultural research management, the NAS committee considers, springs from misallocation of funds. One source of misallocation is the earmarking of funds by Congress for research "that no one can define or for which no scientists are equipped or interested." Cotton, for example, which in terms of cash receipts is half as valuable a crop as wheat, receives twice the amount of research dollars. Some earmarking of funds is an appropriate form of political action but to do it to excess, as the NAS committee believes Congress has done, leads to gross imbalances and serious gaps in the national research effort. The USDA should seek "to communicate better to the U.S. Congress the harmful effects of disproportionate commodity earmarking of agricultural research funds."

A third major fault in agricultural research management is the proliferation of small branch stations. In fact there are two such networks, the state system (SAES) and that administered by the USDA. The SAES system comprises some 300 outlying branch stations and field laboratories, while the USDA system has several major national laboratories scattered throughout the United States and some 200 smaller locations. According to the NAS committee, too much money has been invested in developing small branch stations, whose scientists, as measured by their publications and frequency of citation, are less productive than those working in larger units. In the absence of any evidence that the USDA research is done better or more cheaply than SAES research, the committee suggests the USDA should close down many small branch stations or at least transfer them to the SAES.

Basic Sciences Ignored

Besides the failings in research management, another principal reason for the poor standard of agricultural research is its inadequate interaction with the basic disciplines that underlie it. Plant physiology, for example, is a discipline which might seem quite pertinent to agricultural research, yet a survey of 200 plant physiologists conducted in 1969 indicated that only some 6 percent of their support was derived from the USDA.

As for biochemistry, another presumably relevant discipline, the committee describes itself "appalled" by the low level of support given by the USDA. For example, all of agriculture is dependent on photosynthesis, yet there has been little support for it from agricultural administrators. Nitrogen fixation is another biochemical reaction of more than purely academic interest; the committee describes as "irresponsible" the failure of the scientific administration of the USDA to fund significant research in the subject.

To remedy these oversights, the USDA (the SAES are said to be not quite such bad offenders) should set up a competitive grants program for the support of basic research in all the sciences--biological, physical, and social--that underpin the USDA's mission. (The USDA's existing grants program is inadequately funded and does not allow for a free flow of ideas from the scientific community because the administrators define the program areas.) The new program should be evaluated by a peer review system and administered separately from USDA in-house research. The grants program should account for 20 percent of the USDA's research budget. It is "particularly important" that "recognition be given to the significance of social science research to the agricultural industry and rural people."

A third major failing in agricultural research, as perceived by the NAS committee, is the quality of scientific manpower. Agricultural research suffers from a "paucity of outstanding scientists." Several steps could be taken to improve the research atmosphere. One is to overhaul the way a scientist's performance is reviewed. Practices vary, but in the Agricultural Research Service the head of the scientist's division is often the chairman of the review committee. This is a "too tightly controlled in-house operation." For lack of competent peers, the scientist can be misled as to the quality of his own research and the administrator may not have the benefit of unbiased guidance. The USDA's evaluation system "has failed in many areas to produce top quality bench scientists." The SAES makes broader use of peer review, but both organizations should put outside scientists on their personnel review committees and eschew the practice of using department heads as chairmen.

Another way of improving the climate for research in the USDA would be to break the administrators' virtual monopoly of top jobs, the NAS study suggests. In the USDA's Plant Sciences Research Division only 6.4 percent of a staff of 755 scientists have ratings above the Civil Service GS-14 level, and only 0.5 percent have ratings above GS-15. The system "forces scientists to become administrators if they wish to reach the top grades," a condition that is bound to be repressive of good research. The USDA should allow active researchers to reach the top salary grades and in addition should recruit at all grades from the outside scientific community as well as internally.

The USDA reaction to the NAS study has been expressed by Ned D. Bayley, director of science and education and the official most directly concerned with the subject matter of the report. Bayley told Science that the committee had originally been asked to evaluate the state of agricultural science rather than the management of research. "The report was a little different from what we asked, but that was their prerogative," he says. Bayley does not agree with all the committee's conclusions but believes that many of its recommendations have already been met by a major reorganization initiated before the committee reported. Its study should be understood and interpreted in light of the great success of agricultural research. The committee makes too little allowance for the constraints imposed on the USDA by the shorage of research funds. But

Bayley acknowledges that the "catharsis" experienced by the committee in the course of writing the report is evidence of how closed the USDA system has been to outside review.

Shake-Up of ARS

Many of the administrative criticisms raised by the committee have been addressed by a "real shake-up" of the Agricultural Research Service (ARS), the USDA's largest in-house research agency. In the reorganization, Bayley says, the ARS was decentralized, redesigned along regional rather than subject-matter lines, and a whole layer of administrators was cut out. The entire top staff of the ARS, amounting to some 130 people, was replaced or reassigned; also its former administrator, George W. Irving, retired in 1971. Asked if new people had been brought in by the changes, Bayley said it was more a question of "new faces in new positions." A large portion of the NAS committee's criticisms of poor administrators, he believes, referred to a single large laboratory, the problems of which are now being worked on.

As to the committee's suggestion that 20 percent of the USDA research budget should be devoted to basic research, Bayley says 35 percent is basic right now. Is it true that the agricultural research establishment has neglected such basic subjects as photosynthesis and nitrogen fixation? Bayley cannot say whether or not these have been underfunded in relation to other areas, but he notes that "every time I set a group of scientists to look at their own research they say that they want more money."

Replying to criticisms of the administrative treatment of scientists, Bayley says the ARS has long had a special promotion ladder for research scientists, but the recent government-wide restrictions on grade levels have curtailed its use. He intends to do more recruiting from outside but notes that one reason why the NAS committee pushed this suggestion was that "when Irving retired the committee members asked to be consulted on his successor--they were worried that a regulatory man would be put in charge of the ARS." (The committee was not consulted, but neither was a regulator appointed.)

Probably the most far-reaching of the committee's suggestions for reform is the institution of peer review systems. Bayley sees a "lot of merit" in the idea but harbors several reservations. "You don't launch something like that until you are sure there is going to be acceptance in the field, and there is some resistance there." The ARS supports some 20,000 projects with an annual turnover of about 5,000. To put all these through the peer review system would be a pretty massive undertaking. "If we undertake the peer review system, it will be on a pilot basis so as to learn how to work it." He feels that the peer review system works better for pure research, being less easily matched to mission research. Asked about the NIH, which combines mission research with the peer review system, Bayley remarks that "the NIH has got a lot more money than we have and has been through a plush period." And knowing the business of grantsmanship, one also needs to have a feel for the extent to which a written proposal reflects the research which is actually done." He is not fully convinced of the implicit premise of the NAS committee's recommendation, that peer review leads automatically to higher caliber research. Bayley also evinces a certain distrust of the elitism implied in the peer process. "I feel we sometimes give undue credit to the big shots. The progress of agricultural research is one of the big success stories of our times, but there are no big breakthroughs. It has been built up on the basis of a tremendous number of small advances. We have had four or five Nobel prize winners coming out of agricultural research, but that is just part of it--our success has been based on input from the whole agricultural community."

Is agricultural research a success story because or in spite of the way USDA and SAES research has been administered? Some members of the NAS committee believe that agricultural research is living off past laurels. One of the committee's special panels surveyed significant advances in understanding of nitrogen fixation and concluded none of them emanated from USDA laboratories or was supported significantly by USDA funds. Yet if the state of agricultural research is as debilitated as the NAS committee believes, how has U.S. agricultural production come to be the marvel of the world? This paradox, and further details of the NAS committee's unusual report, will be discussed in a later article.--NICHOLAS WADE

SCIENCE

News and Comment

AGRICULTURE: CRITICS FIND BASIC RESEARCH STUNTED AND WILTING*

The basic research performed by federal and state agricultural research organizations is of meager quality, suffers from a "shocking lack of intellectual leadership," and is guided by policies detrimental to the interests of agriculture. This is the opinion of a number of well-known academic scientists who studied the agricultural research enterprise under the auspices of the National Academy of Sciences (NAS). Administrators in the Department of Agriculture (USDA) do not accept their conclusions but have not come up with a point-by-point rebuttal. Agricultural scientists have not yet had an opportunity to respond to the academy's criticisms because the report, although completed nearly a year ago, has been restricted to top administrative levels within the USDA (it is now available to the public*).

The academy report is the work of a blue-ribbon committee of basic and agricultural scientists chaired by Glenn S. Pound, dean of the College of Agriculture at the University of Wisconsin. In its main report (summarized in Science, 5 January), the committee faulted the agricultural research establishment for supporting pedestrian and inefficient work, for neglecting basic research, for poor coordination between the federal and state systems, for inept management of scientists, for grossly inadequate programs of staff improvement, and for administrative philosophies repressive to the vitality of scientists. The list of charges, resembling in completeness that brought against the last of the Avignon popes, is partly based on a series of studies made by panels of the committee and published as appendices to the main report. This article discusses the panel surveys of basic biological research. Other articles will consider the panel reports on forest, environmental and sociological research, and the agricultural research enterprise in general.

The panel reports on basic research are addressed to the 200 or so laboratories of the USDA's Agricultural Research Service (ARS), as well as to the state agricultural experiment stations (SAES) in each state of the union. "The present health of agriculture-related biochemical research is not only poor, but deteriorating.... Basic research is supported poorly in most agricultural research units, and is actually discouraged in many USDA units surveyed, even when it is clearly related to the unit's research mission," concludes the NAS panel on biochemistry. Authors of the panel report are Harlyn O. Halvorson of Brandeis University and Robert W. Holley of the Salk Institute. (Holley formerly worked in an ARS laboratory at Cornell where he did his Nobel-prize-winning study of transfer RNA.)

Appalling Lack of Support

According to Halvorson and Holley, the USDA has relied on other government agencies to support most basic research relevant to agriculture. For example, a survey of the American Society of Plant Physiologists in 1969 showed that members received less than 10 percent of their funds from the USDA. Since then other government agencies have retrenched on their support of the plant sciences, but are still largely responsible for what strength remains in biochemical research related to agriculture. Although outstanding basic research is conducted in some USDA labs, agriculture has been neglecting its responsibilities even in fundamental problems of primary concern to its mission, such as photosynthesis and nitrogen fixation. The panel looked closely at these two fields and, in the case of photosynthesis particularly, was "appalled at the lack of support by administrators who have responsibility for agricultural research."

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*Report of the Committee Advisory to the U.S. Department of Agriculture. National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151.

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Basic work on photosynthesis, the panel asserts, is "almost without exception carried on in private and state universities and research institutions, without support from the USDA.... At present one is reasonably safe in asserting that not one of the nation's outstanding leaders in photosynthesis works in a USDA laboratory and that not one receives his major support from USDA funds." (It should be noted that the panel explicitly excludes from its definition of photosynthesis work relating to overall crop yields and the effects of pollutants, areas in which the USDA and state contribution is admitted to be appreciable.)

The panel cites the following evidence for its statement:

o Of 56 papers on photosyntehsis presented by U.S. participants at the 1969 International Botanical Congress, only two acknowledge support from the USDA.

o Of a list of ten full-time USDA workers on photosynthesis furnished by a well-known professor in a leading college of agriculture, the names of only three were even recognized by the editor of Plant Physiology.

o Of the 35 reviews of photosynthesis published in Annual Review of Plant Physiology since 1950, not one was written by a USDA scientist, and only six were written by scientists associated in some way with state experiment stations.

o A review of 136 state and USDA research projects in photosynthesis was conducted by another NAS panel, chaired by Kenneth V. Thimann of the University of California, Santa Cruz. On the basis of computerized summaries of the project (known as CRIS reports, and roughly equivalent to an abstract) the Thimann panel graded the projects on the same scale as is used by National Institutes of Health and National Science Foundation in assessing grant applications. Only the top third of the projects fell in the range (1.0 to 3.0) that would have received funding from the NSF. The panel notes that "had the proposals been subject to review by peers...large sums of money would have been saved." Most of the top 10 percent of the projects were carried out at Cornell University and the University of Connecticut.

The Halvorson-Holley panel concludes that those responsible for research administration in agriculture have "minimized the importance of photosynthesis," which the panel considers to constitute a "shocking lack of intellectual leadership."

Turning to nitrogen fixation, the panel's method has been to identify eight substantial advances made in understanding nitrogen fixation in the last 20 years, together with the source of support on which the advances were made. The sources include the NIH, NSF, chemical industry, and others. State experiment stations contributed toward five of the advances, the USDA to none (except insofar as it provides general support to experimental stations). The panel blames the USDA for providing only token support of research on nitrogen fixation and for having shared in none of the substantial advances in the subject over the last 40 (sic) years.

A separate panel report, written by Halvorson, examines the extent of support of molecular biology by agricultural institutions. Following the same procedure used by the Thimann panel to assess work on photosynthesis, Halvorson rated 139 state and federal agricultural projects on the basis of the CRIS reports in the USDA's computerized information system. The projects were rated on the scale used in the NSF/NIH peer review system (1 counts high, 5 low). Halvorson notes that since the NSF and NIH rarely approve molecular biology proposals ranking below 2.0, none of the projects supported by the USDA or by the USDA and others would have been funded by these agencies (see Table 1). The few projects that would have been funded accounted for only $133,000 of the $3,700,000 expended on all 139 projects.

Table 1. Quality of USDA/SAES projects in molecular biology.

Rating	USDA No.	USDA %	USDA + others No.	USDA + others %	State stations and others No.	State stations and others %
1.0 to 1.9	0	0	0	0	0	0
2.0 to 2.9	2	7	14	29	33	52
3.0 to 3.9	16	60	29	59	20	32
4.0 to 4.0	9	33	6	12	5	8

As another measure of the agricultural effort, Halvorson analyzed the source of support of all the articles that appeared in the Journal of Molecular Biology, one of the leading journals in the field, during 1970. None of the authors was supported by USDA funds and only two received some support from state agricultural stations.

USDA-supported projects in molecular biology are of consistently lower quality and higher cost than those funded by other agencies, Halvorson concludes. He finds it distressing that important problems in molecular biology, such as plant viruses, plant meiosis, and nucleic acid synthesis in seeds, are supported by nonagricultural sources, which are now drying up.

How accurate are the academy panels' judgments? Do they tell the whole story, or are their conclusions designed to prove a particular point? The report of the Pound committee was reviewed by the top level group that coordinates federal and state research, the Agricultural Research Policy Advisory Committee (ARPAC), but the ARPAC reviewers did not feel it "appropriate" to attempt a detailed critique of the report. "There is no point in our going back and feuding with them," said one USDA official.

A general criticism voiced by ARPAC and every USDA official asked to comment on the report is that it was unfair to judge the quality of agricultural research on the basis of the CRIS system reports. The CRIS reports are abstracts of not more than 500 words or so, whereas grant applications to the NSF and NIH are far more detailed.

Some USDA administrators see the Pound report as reflecting more on the adequacy of the CRIS system than anything else. Members of the Pound committee panels, on the other hand, say that the CRIS reports are an adequate even if not ideal basis for judgment. "Even in an abstract, if you have anything original it clearly appears. I don't think that is a valid defense," says Thimann. Even if an individual project cannot fairly be judged on the basis of a 500-word abstract, the point at issue is whether a panel of experts can make assessments of this kind which are true on average. Nor were the CRIS reports the only yardstick of research quality.

Pound Committee Self-Serving

Another general criticism of the Pound report is that its attack on the USDA/SAES's basic research was self-serving. "It appears that the prime movers of the NAS study were motivated by trying to get more extramural funds [grants awarded by the USDA to universities]," comments Hugo O. Graumann, assistant administrator of the ARS for plant and entomological sciences. "Here you had a group of scientists whose support from the NIH and NSF for their so-called basic research had dried up. They sent their proposals to Agriculture and were shocked to find we couldn't fund them." The Pound report certainly makes no secret of its belief that the USDA should shoulder the burden of supporting basic research in plant sciences that other agencies have dropped, and explicitly recommends that the USDA should devote 10 percent of its total research budget to extramural grants for basic research. This viewpoint could perhaps have tinged some of the committee panels' assessments, but that it might have made a major difference to the report seems less certain.

Evident from discussions of the report with USDA officials is that their definition of basic research and that of the Pound committee do not have a great deal in common. Administrators argue that ample basic research--much of which the Pound committee failed to detect--is conducted as part of the research devoted to the various crop plants. Between 30 and 40 percent of the budget of the ARS Division of Plant Sciences was devoted to basic research, says Graumann, the director of the division until its abolition in last year's reorganization of the ARS.

Some ARS officials tend to distinguish between basic research and what they call academic research. According to this view, scientists at Harvard and Yale have spent thousands of dollars from the NSF on photosynthesis research, none of which could be translated into more efficient crop production; nor is there much point in sending ARS scientists to the international congresses where such results are discussed because the same kinds of things are being said there now as were said 20 years ago.

This viewpoint is to some extent shared by one of the few agricultural scientists whom Pound committee members would accept as a distinguished basic researcher, Sterling B. Hendricks. Hendricks, now retired from the ARS laboratory at Beltsville, Maryland, believes it is doubtful, odd as it may seem, that knowledge of photosynthesis has really been useful in agriculture to date, although it may be in the future. The question which the Pound committee neglected, in his view, is whether the basic research of the ARS is good for agriculture, not whether it satisfies academic criteria such as publication lists. Whatever the immediate relevance of photosynthesis, the Pound committee position is that it is "kind of ridiculous," in one member's words, for the major government organization dealing with plant growth not to be supporting good basic work in the subject.

The USDA believes it is doing just that. Asked to comment on the Halvorson-Holley panel statement that the USDA supports none of the country's leading researchers in photosynthesis, a senior ARS plant physiologist cited the names of three ARS scientists doing outstanding work. A panel member agreed, on being queried about these names, that two of them were first-rate scientists (he had not heard of the third) but said they were studying factors that affect photosynthesis rather the process itself. "If the USDA could only produce two shining stars, this is a pretty poor showing--we could show as many good people in a single department," this member added.

The size of the USDA's efforts on basic plant science research is hard to assess. The ARS has 170 plant physiologists on its payrolls (reduced from 188 a few years ago). Estimates of the number working on photosynthesis range from 12 to 20 scientists. Assuming for the moment that the Pound committee is correct in asserting that basic science has been neglected, how could such a situation have come about? Several possile contributory factors can be identified.

First, until last year's reorganization, and to some extent even now, the ARS was organized along commodity lines with an administrator known as the branch chief responsible for each crop. The branch chiefs, who in effect made most of the decisions on research programs, tended to look for short term results of immediate relevance to their own crop. Basic research was "pie-in-the sky" for some branch chiefs, says an ARS plant physiologist. He adds that other chiefs were aware of the need for a good basic research program and would have created one, had it not been for the restrictions on funds and on hiring that have been placed on the ARS during the last few years.

Second, there seems to have been no one above the level of branch chief in the old ARS organization to stand up for the importance of basic research. Graumann, the former director of the plant sciences division, indicates that the impetus for basic research had to come from the scientists at the bottom, not the administrators at the top. "ARS administrators make no attempt to encourage or discourage basic research," he told Science. "This is left to the basic scientists. The administrators are concerned with fulfilling broad missions, basic and applied, such as improving the production efficiency of corn or oats. At no time did I bother myself with whether scientist Smith should do basic research in the area of photosynghesis. We didn't say so much should be reserved for research on photosynthesis or nitrogen fixation. We assumed the scientists at the bench level who were working with this kind of thing would, in counsel with their branch chiefs, see the critical needs to which they should address themselves." Asked what kind of scientific decisions an administrator would make, Graumann replied, "He doesn't, other than making sure we have a proper balance of scientists to accomplish our missions."

What kind of opportunity is there for ARS scientists to do basic research? Administrators say there is ample opportunity, and point with pride and some pain to the instance of Holley. Holley, however, is not a good witness for their argument. "There is the freedom within the system to support basic research," he told *Science*, "but it just isn't used. The reason it worked for me was that the director of my lab, W. H. Allaway, thought my work was important and gave me the support to do it full time. The previous director had thought it was worth half my time. But for Allaway, I would not have finished the structure [of the yeast alanine transfer RNA molecule] before someone else did and I would not have gotten the Nobel prize." Holley adds that, in his view, "Few administrators in ARS have the foresight to support basic research, because they don't recognize its importance for their own mission.

Besides the luck of the draw in the attitude of their administrator, another kind of restriction on "bench scientists," as scientists are referred to in the ARS, is the unwritten rule that they must conduct their research on the crop plant for which their funds are earmarked, whether or not it is the most suitable organism for the purpose. Even Hendricks, who headed a lab specially assigned to do basic research, set himself the limitation of always working on seed plants. ARS scientists say this restriction has eased somewhat since the reorganization last year, but H. R. Carns, chairman of the newly created Plant Physiology Institute at Beltsville, told *Science* that "If money has been appropriated for tobacco, then people funded by it are fairly well limited to working with tobacco. They may use other plants to supplement their work but only to supplement it." Scientists could work on *Chlorella* (an alga frequently used for basic studies of plant biochemistry) but it would require "careful assessment," Carns said. No one at the Plant Physiology Institute is working on *Chlorella* at present. Asked how serious a handicap restriction to a crop plant might be, the editor of *Plant Physiology*, Martin Gibbs, rated it as 'serious to quite serious.' "If you are trying to get to the basic cellular level, crop plants are not necessarily the organisms I would select. But with ingenuity you can get round this, providing that you have people who can devote the time and effort to doing so," Gibbs said.

With administrators leaving research decisions pretty much to the branch chiefs, the branch chiefs having an immediate duty to solve the short term problems of their particular crop, and the "bench scientists" ruled by their particular branch chief's attitude toward basic research, it is possible to see in principle how a strong fundamental research effort of the type advocated by the Pound committee could have failed to flourish within the ARS administrative system. A similar predominance of short term needs seems to have prevailed in the state agricultural experiment stations, although it is tempered by their responsibility for training researchers.

Even assuming the Pound committee is largely correct in saying that the federal and state basic research effort is poor and needs to be improved, that does not necessarily mean that the present activities are not in their own way of benefit to agriculture. Moreover, it is easier to change directions on an expanding budget, and for the last few years the ARS has been held on tight rein. In making its case for a better basic research effort, the Pound committee has said some things which are bound to hurt. Maybe understandably, administrators in the ARS seem more interested in stonewalling the committee's arguments than in addressing the issues they raise.--NICHOLAS WADE

THE WAR OF THE PARTS AGAINST THE WHOLE

by John W. Gardner

Alexander Solzhenitsyn, the great Soviet novelist who defected to the West, is highly critical of the Soviet Union, but he also has some rough things to say about us. "The Western system," he says, "in its present state of spritual exhaustion does not look attractive...no weapons, no matter how powerful, can help the West until it overcomes its loss of will power."

Felix Rohatyn, the brilliant, tough-minded businessman who did so much to save New York in its time of crisis, says, "Commitment is not fashionable; cool is the order of the day...we face the possible loss of our most precious asset, Western democracy... all because we are lazy, cynical and self-indulgent, unwilling to make the effort..."

And Mike Mansfield on a trip home from Japan drew a comparison between the state of our economy and that of Japan, and said "We have to pull up our breeches and roll up our sleeves and get down to work."

Most Americans who hear such statements agree with them, yet the words have virtually no effect. Why? Because every one thinks the statements apply to some other group of Americans. Not to me. Not to my group. Not to my kind of American...and that reaction says a lot about what is really undermining us--not laziness or self-indulgence or spiritual exhaustion, but loss of trust in one another and loss of a sense of common purpose.

Of course, it is to be expected that the varied groups in American life will come into conflict. They always have. But in the decades following World War II, there has been a spectacular expansion in the number and diversity of such groups--and in their capacity to organize themselves for combat. In most of these groups the element of cohesion is supplied by a common economic activity or interest. But others seek redress of grievances that they have suffered at the hands of society. And then there are the "issue" groups, members of which may come from diverse social, economic, or occupational backgrounds but have in common a shared concern for advancement of a particular public policy.

I want to emphasize that most of the groups have legitimate concerns; some of them have concerns that are, by any standards, urgent. But as more and more of them learn how to organize for effective action, and how to slug it out in the adversary mode, what started as healthy competition has developed destructive aspects. If we can't face that we're lost.

How many times have we seen a major American city struggling with devastating problems while every possible solution is blocked by one or another powerful union or commercial or political interest? Each has achieved veto power over a piece of any possible solution, and no one has the power to solve the problem. Thus, in an oddly self-destructive conflict, the parts wage war against the whole. And the conflict will destroy us unless we get hold of it.

The war of the parts against the whole is the central problem of pluralism today. We're moving toward a society so intricately organized that the working of the whole system may be halted if one part stops functioning. Thus our capacity to frustrate one another through non-cooperation has increased dramatically. The part can hold the whole system up for ransom (as the air-traffic controllers, among others, have so vividly demonstrated).

To comprehend the paralysis of government as the policymaker experiences it, imagine a checkerplayer confronted by a bystander who puts a thumb on one checker and says, "Go ahead and play, just don't touch this one," and then another bystander puts a thumb on another checker with the same warning, and then another bystander and another. The owners of the thumbs--the interest groups--do not want to make the game unwinnable. They just don't want you to touch their particular checker.

The grievances of businessmen, of labor, of farmers are familiar. But it is not widely recognized that virtually every group in the society nurses comparable grievances--schoolteachers, policemen, truckers; the list is endless. The various groups feel victimized, besieged by hostile forces, fighting with their backs to the wall. A physician friend of mine said "We want to serve the society, but it's hard to serve when you're under constant attack." Civil servants feel they are mocked and denied the respect that is their due. Each group believes that it is doing a job of importance that is unappreciated; that it is being pushed around by undeserving others.

There is a sense of helplessness, of being acted on and unable to act. A business executive said to me, "We feel as though we're huddled in a bomb shelter, never knowing when government and the politicians will drop the next blockbuster on us." A sheetmetal worker with a $28,000 income and a pleasant suburban home told a journalist, "I frankly think nobody in the whole society gives one damn whether folks like me live or die. We're not poor so we get no sympathy, and we're not rich so we have no power."

Each group is wholly convinced of the rightness of its aims. Each has grave doubts about the integrity of other elements in the society. Any suggestion that a particular group curb its self-interest for the common good is seen as a hostile move to undermine its position. People who think of themselves as victims are in no mood to collaborate with others to shape a constructive future. The attitudes of each element toward the others are more likely to be accusatory and intransigent. A fireman in one of our major cities said in a television interview, "Naturally we're bitter. We risk our lives and who cares?"

Each group, believing itself to be engaged in a lonely fight for survival, develops a kind of collective paranoia and irrationality. Angry farmers drive their tractors down the avenues of Washington. Firemen refuse to respond to alarms. Independent truckers block the highways. A trade association uses its Congressional contacts to scuttle constructive legislation. Extreme positions come naturally in such an atmosphere, as does invective. One would hardly guess that all have a common stake in the health of the society.

"But," says a scientist friend of mine, "we contribute to the common good just by existing." Business people express comparable sentiments, and so does every other element in the society. A union leader says, "When we improve the lot of the workers, that is the public good." They believe in the value of their roles for the good of the whole society--and we can certainly accept that kind of healthy self-affirmation. But when battle lines are drawn and tensions rise, the good of the whole society literally disappears from view. We all know the consequences. At this moment, we are a nation in disarray. There is no point in mincing words.

All of this is ironic when one recognizes that never before have so many of these groups been so highly organized and effective in action. They know how to lobby. They know how to "use" the media. They establish "beachheads" in government agencies, sometimes even force reorganization of an agency to suit their purposes. And they affect public policy.

It is entirely legitimate for such groups to organize themselves. It is their constitutional right to seek to influence government, and often what they want is not unreasonable. But what do we do when the factional strife becomes more than the system can bear?

We might begin by recognizing that the reconciling of multiple conflicting interests that cannot be reconciled in the market place or elsewhere is not an unfamiliar or inappropriate task for our political and governmental institutions. It is one of their central and traditional functions.

All too rarely have any of the organized groups shown the slightest concern for the health of the political process. All too often they have been satisfied with incompetent, disorganized or even corrupt government, provided that they could influence it. But a weak and corrupt government will sell out to a rival interest group just as cheerfully, and may also surrender to a demagogue if one arises.

Every organized interest should encourage the effective and equitable functioning of government. This does not mean more or bigger government. It might mean less government. Our political and governmental processes, functioning at their best, are designed not to impose a central solution but to preside over the peaceable competition of conflicting interests, and to reconcile those interests within the framework of our shared purposes. Ways must be found to counter the centrifugal forces of interest-group competition, lift the paralysis that afflicts the political process, and make possible the development and execution of coherent natonal policies. If centrifugal forces continue to gain strength, if we continue our neglect of commonweal priorities, the system will dissolve into chaos.

I cannot, in this brief talk, outline the areas in which solutions are being sought; but as many of you know, constructive thinking is now going on as to how we can make the parties, the Congress, the Presidency more effective instruments for mediation and consensus-building among the multiple conflicting interests. There is much that we can and must do to make our political and governmental processes more effective in resolving conflict, building coalitions, and achieving results that serve--as well as may be--the good of the whole.

But government cannot do it all. When the particularistic interests become too fierce, when each regards compromise as betrayal, when each has through skilled lobbying achieved veto power over a piece of any proposed solution--governing becomes virtually impossible.

When you read that the public thinks government is not doing a good job, it is worth remembering that the public--split into multiple intransigent groups--is doing its share to make the nation ungovernable. Maybe "the public" should reflect on what it is doing to the structure of government and the process of governing.

Our pluralistic philosophy invites each organization, institution, or special group to develop and enhance its own potentialities. But the price of that treasured autonomy and self-preoccupation is that each institution concern itself also with the common good. That is not idealism; it is self-preservation. The argument is not moralistic. If the larger system fails, the subsystems fail. That should not be such a difficult concept for the contending groups to understand.

A society in which pluralism is not undergirded by *some* shared values and held together by *some* measure of mutual trust simply cannot survive. Pluralism that reflects no commitments whatever to the common good is pluralism gone berserk. One can understand that occasionally single-minded pursuit of its own purposes may render a group psychologically incapable of lending itself to any worthy common purpose. But when virtually all groups feel that way all the time, something has to give.

Today we have reached and passed the danger point of divisiveness. Faction is king. And the divisiveness feeds on itself. People finding themselves surrounded by factional strife end up behaving more selfishly than they otherwise would.

Some people argue that it is inflation that is turning groups against one another--but the fragmentation has been growing steadily over many years now. Other observers attribute our disintegration of national purpose to moral deterioration or a loss of motivation. Such critics fail to account for the fact that Americans show ample motivation and character in pursuing the interests of their special group.

This is a moment when the innumerable interests, organizations, and groups that make up our national life must keep their part of the bargain with the society that gives them freedom by working toward the common good. Right now. In this time of trouble. Their chance for long-term enjoyment of pluralism will be enhanced by a commitment to the common good as we go through this difficult passage. At least for now, a little less *pluribus*, a lot more *unum*. Each group should reach out to other elements in American life trying to understand and connect. If we do not pull this shattered country together, we haven't a chance.

I do not believe for a moment that we can solve our problem simply by exhorting all groups to have regard for the good of the whole. There are many other measures that we must take, particularly, as I said earlier, with respect to the functioning of our political and governmental processes. But along with all the other measures we undertake, I propose that we face squarely what unbridled factionalism is doing to us. Let us honor the reasonable striving of groups to achieve goals that they share, but let us also have regard for the health and coherence of the whole society. If we do not it will surely fail.

For my part, I am not without hope. Each of the various contending groups is composed of well-motivated Americans who want the best for their country. And there is more that unites us than divides us.

Beneath the currently fashionable self-preoccupation there are in most Americans motives that can be put to work in the service of the nation. We do want a good future for our children. Most Americans are problem-solvers by nature; they want to make our system work, and they are ready to do what is necessary to that end. They have never loved government, but they love their country and want the best for it. And they would feel better about themselves if they were working toward shared goals.

I think anyone reviewing our two-hundred-year history must conclude that we have always exhibited in full measure the untidiness that one associates with democracy. But one must also conclude that we have shown an extraordinary capacity to shape up when we have to. What I am saying is, now we have to. It's shape-up time!

* * *

COSMOS CLUB Lecture. Washington, D.C. April 1980.

Commissioned Paper V

AGRICULTURAL RESEARCH IN NON-LAND-GRANT UNIVERSITIES

R. C. Lewontin

Office of Technology Assessment

September 1980

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A Typology of Institutions

It is not possible to get a clear grasp of the role of "non-land-grant" institutions in agricultural research without making a more careful and detailed description of American universities. The relationship between schools of agriculture and non-agricultural parts of universities is varied and complex, and the relationship of non-agricultural faculties to agricultural research varies with the kind of institutional arrangements that exist. Rather than making an arbitrary juridical distinction between land grant and non-land grant universities, we need to distinguish four sorts of institutions.

1. Private Universities. Large private universities such as Harvard, Stanford, Chicago, several Institutes of Technology, Washington University, Rochester, and smaller college-universities which carry on significant research such as Wesleyan, Reed College and Amherst, lie at one extreme of the spectrum. These institutions have no relation to schools of agriculture, receive no general support from federal, state or local government, and support their natural scientific research virtually entirely from specific government grants and contracts or corporate contracts, with small amounts deriving from private foundations and endowment income. This is a relatively small group, about three dozen institutions, but they account for about 60% of total federal expenditures in universities for research and development.[1]

2. Autonomous State Universities. In this group are those institutions which, while they may fall under the same high level authority as the agricultural university in the state (Chancellor, Board of Higher Education, State University Trustees, etc.), are physically removed, usually at a considerable distance, from the agricultural campus and are even further removed in spirit and intent. For example, the San Diego and Santa Barbara campuses of the University of California are totally unrelated to the agricultural campus at Davis. (But Berkeley and Riverside have peculiar historical relations to agriculture to which I return below.) Other examples are The University of Oregon at Eugene with Oregon State at Corvalis, The University of Texas at Austin with Texas A. and M. at College Station, and The University of Michigan at Ann Arbor with Michigan State University at East Lansing. The physical separation of these "liberal arts" campuses from the agricultural institutions, as well as their administrative autonomy, reinforces the intellectual and cultural differences that their faculties and students feel from what they regard as their inferior colleagues at the "cow college" campus. As in the Private Universities, the chief source of research funds in the Autonomous State University is individual government grants and contracts. The relationship of research and teaching in these Autonomous State Universities to agriculture is essentially the same as the relationship of the Private Universities to agriculture.

3. Integrated State Universities. At some state universities, like the University of Illinois, the agricultural and non-agricultural parts of the university are in close physical contact, they are under the same local administration, the faculties are in contact on a daily basis and there is a good deal of intellectual and cultural flow between agricultural and non-agricultural sectors of the faculty. Some examples aside from Illinois are The University of Wisconsin, The University of Minnesota (despite the partial physical separation in Minneapolis and St. Paul), The University of Massachusetts at Amherst and Ohio State University at Columbus. An anomaly that clearly falls in this category operationally although not technically is Cornell. Although only the College of Agriculture is state supported, Cornell in most respects operates like other Integrated State Universities. Another anomaly is the University of California at Berkeley. Although the Regents attempted some years ago to separate clearly the agricultural campus at Davis from the liberal arts function at Berkeley, they did not wholly succeed. So, for example, two of the most prominent members of the Genetics Department in Berkeley until their retirement were experts in animal breeding, and another is a forestry geneticist. In like manner, because of the physical presence of the Citrus Experiment Station at Riverside, that "liberal arts" campus has had some close contacts with agricultural research.

4. Agricultural and Technical Universities. This is the group of classical "land-grant colleges", most of which are now called universities (North Carolina State University, Michigan State University, Arizona State University, etc.). They are dominated intellectually by the School of Agriculture or, frequently, by the School of Engineering or School of Mines, with liberal arts departments often relegated to a service function.

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[1] National Science Foundation. "Federal Support to Universities and Colleges." (NSF 19-32),p.33.

The point of this typology of institutions is that there is a clear distinction, as far as agricultural research is concerned, not between land-grant and non-land-grant institutions, but between the Private Universities and Autonomous State Universities on the one hand, and the Integrated State Universities and Agricultural and Technical Universities on the other. Private and Autonomous State Universities play essentially no role at the present in agricultural research, and are intellectually and culturally divorced from such concerns, while Integrated State Universities are much closer to agricultural institutions in their interests and in some of their activities.

Two Cultures: Basic and Applied Science

It is sometimes thought that the lack of agricultural research in the Private and Autonomous State Universities is a consequence of the lack of research funds and of easy access to the physical plant used in agriculture. While there is no doubt that the lack of available funding in the past has occasionally blocked such research (I, myself, have had that experience) and that the lack of an experimental farm may inhibit some sorts of agricultural research in Private and Autonomous State Universities, the main impediment to agriculture research in such institutions lies elsewhere. It lies, in fact, in the structure of status and rewards in the scientific community.

There is a strong division socially and intellectually that goes through American university and college science. On the one side is a group of natural scientists who regard science as simply a part of general intellectual life. In a tradition that harks back to the genteel science of Victorian and Edwardian Oxford and Cambridge, these scientists place the greatest value on the most generally framed questions and on those subjects that are most divorced from practical problems. They prefer employment in the Private or Autonomous State Universities. When they work in Integrated State Universities they avoid, for the most part, involvement in agricultural questions. A few work in Schools of Agriculture, but in my field inverviews I have found them to be very assertive about the "basic" nature of their work, and the importance of "basic science." These "basic" scientists belong to their own scientific societies, publish in journals chiefly devoted to "basic" science and even avoid, when possible, using agricultural plants, animals or pests as their experimental material. A student who wishes to make his or her way in this part of the scientific world in say, genetics, is well advised to experiment on the laboratory organism Drosophila rather than on species of insect pest, say the Mediterranean Fruit Fly. There is a curious assumption that results obtained on a laboratory species are somehow "more general."

On the other side are the "applied" biologists who typically work either in Integrated State Universities or Agricultural and Technical Universities. They believe their constituency to be farmers (or more rarely consumers) and may come from farm backgrounds. On the one hand they feel what they do is worthwhile, but on the other they have some sense of inferiority, imposed on them by the "pure" scientists and by general cultural values. They tend to publish in, say, the Agronomy Journal rather than Genetics and go to the Poultry Breeders Roundtable rather than the American Association for the Advancement of Science meetings. Only in the last 10 years have they been elected to the National Academy of Science (in a special section).

The existence of these two cultures is fundamental to our understanding of the role of Private and Autonomous State Universities in agricultural research in the past and in the future. The chief barrier to the performance of significant amounts of agricultural research in these universities is that the social institutions of status and reward within science and the internalized values of Private and Autonomous University scientists put a strong pressure on so-called "basic" rather than "applied" research. This set of values is reflected also in the attitudes and behavior of university authorities. Presidents, Deans and Department Chairmen of non-agricultural institutions repeatedly express the goal of their universities in terms of general knowledge, of basic science, of "understanding the universe," of "understanding the human condition," of contributing to knowledge as a goal in itself. These values permeate the decisions on hiring and promotion of faculty, the allocation of space and resources.

The problem is most clearly illustrated in the hiring and promotion process. In a

Faculty of Agriculture the decision to hire a young faculty member in, say, plant pathology is partly dependent upon his or her willingness to assume responsibility for a particular set of problems that the Department imposes on itself, say virus diseases in vegetable crops. Promotion will depend in part on a record of publication of research papers in recognized journals, but also in large part on the success of the research worker in dealing with specific practical research problems that have arisen, in dealing with the producer constituency and in making important advances in the general knowledge of particular crops or diseases. For the "basic" scientist in the non-agricultural institution the criteria are quite different. In practice the determination of original hiring and later promotion is made (putting aside for the moment illegitimate but frequent personal considerations) on the basis of the candidate's reputation among his or her peers for originality, intellectual brilliance, ability to choose "important" problems in the field and, of course, success in solving the problems that the scientist has set for him or herself. While publications, as evidence of such success, are important they are less so than is thought. Reputation, which is gained only in part by publication, is the critical issue. This means that the social values of "basic" science are reinforced by the process of hiring and promotion. It has now become a common feature of scientific life that a young assistant professor, about to be considered for promotion to tenure, will make a trip around the country, touching base with prominent people in his or her field, telling them of his or her latest unpublished work, giving informal talks.

The result of the cultural process I have described is that priorities for research in Private and Autonomous State Universities, and in large part in Integrated State Universities outside of the Faculty of Agriculture, are set not by the university, but by the producers and consumers of the research itself, that is by the "basic" scientific community at large. This process is also now penetrating the Faculties of Agriculture themselves. Certain individuals, the "basic scientists" in the agricultural research system, have their promotions and rewards determined by the same criteria as those outside agricultural research, on a parallel but independent track from their "applied" colleagues. Most Departments have one or two such people. In some sense they are enjoying extra-territorial rights in a foreign country.

I have repeatedly put "basic" and "applied" science in inverted commas because I am unable to distinguish between them on any simply objective basis. They are differentiated in large part by a social convention that operates within a scientific field at a particular moment. There is no way of knowing from evidence entirely internal to the actual research itself whether my own study of genetic differences in the esterase enzymes of aphids from different populations is for a study of how species form ("basic" research) or in order to choose the most effective insecticide ("applied" research). It is not an individual research result, but a pattern of integrated research problems that determines whether some practical consequence can or cannot come from a specific research work. Research is "basic" or "applied" depending upon the context in which it is done and what is done next with it. It is not true, as is sometimes claimed, that "basic" science establishes general principles while applied science uses those principles in specific cases. "Basic" science is filled with people who are studying, for example, the evolution of a particular species and whose interest lies in elucidating the evolutionary history of that species. A particularly illuminating case is the study of the wild ancestors and evolution of maize. This is considered "basic" science because it is a study of evolution, a subject that is considered legitimate by "basic" scientists. Yet there is nothing especially general to be learned from knowing which wild species was the progenitor of cultivated corn. "Basic" science is not defined by any positive criteria. If it is anything, it is science whose results cannot be put to any immediate use.

The Past Role of Private and Autonomous State Universities

It is ironic that university agricultural research in the United States began at Harvard and Yale. These institutions appointed Professors of agricultural chemistry in the 1840's as a result of the immense interest in soil chemistry and fertilizers that had spread from Leibig's laboratory in Germany. These Professors had essentially to earn their own keep by soil analyses. In the 20th century Harvard maintained some research and teaching in relation to agriculture through three institutions. The Bussey Institution in Jamaica Plain trained many of the leading geneticists of the post- World War I generation. While the original emphasis was on plant and animal breeding, nearly all these geneticists, Castle, Wright, Dunn, Little, left applied research and became integrated into the Private University-Autonomous

State University milieu. The Bussey Institution is now essentially extinct. The Arnold Arboretum continues research in horticulture, but almost entirely on ornamentals. The Cabot Foundation supports research on photosynthesis and plant physiology which is ostensibly oriented toward agriculture, but in fact is regarded as "basic" research. Typical of Harvard's orientation in "agricultural" research was the work of P. C. Mangelsdorf, who had originally worked on corn in Texas, but who spent his entire career at Harvard studying the evolution and archeology of the primitive ancestors of corn in an attempt to reconstruct the evolutionary origin of maize. This study of a cultivated crop received legitimacy at Harvard, as pointed out above, because it was a study of evolution of the species, and not of its present production.

Harvard is by no means atypical. Private and Autonomous State Universities have carried out extensive research in plant physiology, especially photosynthesis, plant embryology and development, entomology, ecology, genetics including the theory of breeding systems, and animal physiology, all of which subjects are of importance in agricultural research. Yet the mark of nearly all this research has been a distance from direct application or the explicit attempt to solve direct practical problems. The major exception to this rule has been in agricultural economics where some of the best known studies have been carried out at, for example, Chicago and Yale.

Occasionally very special situations arise in which immense payoffs will accrue to an investigator who will turn toward agricultural research in a "basic" science milieu. A case in point is the possibility of transferring nitrogen fixation to non-leguminous plants, especially grains, by the new methods of recombinant DNA technology. Such research is being carried out by Prof. F. Ausubel at Harvard, among others, and is considered a legitimate subject for work there. It seems fairly clear, however, that if that research succeeds, it will not be carried past the demonstration stage at Harvard, but will be developed to the point of actual practical use either by agricultural experiment stations or private corporations. The original demonstration and pilot experiment will have exhausted the legitimacy of this subject in the Private University milieu.

Some agricultural research is being carried out outside the Faculties of Agriculture, chiefly in the Integrated State Universities. The frequent contacts between agricultural and non-agricultural scientists in Integrated State Universities has made these institutions particularly valuable to agricultural research. For example, at the University of Massachusetts a senior professor of neurophysiology in the Zoology Department who came to the State University from Princeton after a very distinguished career there now regularly collaborates with entomologists from the Faculty of Agriculture. At Madison, Berkeley, Cornell and Riverside, geneticists exploit the immense possibilities for research in cultivated systems in collaboration with agricultural scientists. The most immediate way to increase the involvement of "basic" scientists in agricultural research is to selectively encourage, say through giving preference in Hatch funds, such collaborations at Integrated State Universities, where the physical opportunities and intellectual exchanges exist. In a number of cases, as for example the University of Minnesota and Cornell, agricultural scientists and "pure" scientists are mixed in departments of "Biological Science." Such departments are particularly susceptible to an increase in the applied research component.

Future Possibilities

Given that the lack of agriculture research in Private and Autonomous Universities is largely a consequence of the socialization of scientists and the status and reward structure of their profession, it is not likely that funding alone can make significant changes. Scientists who have difficulty finding funds for their research will tend to continue to seek them from various sources for the same research or else may shift to a more "fasionable" area, but still within the area of basic science legitimacy. They are unlikely to shift into agriculture just for the money becuase they will put their careers in jeopardy and will sacrifice the approval of their peers. The almost certain fate of large amounts of money for agricultural research being made available to basic scientists is that the program will be subverted. University scientists are past masters at rewriting research grants so that they appear to be relevant to some stated public purpose, while continuing to do the same research as before.

That has been the case for health related research funds which are widely disbursed for research projects with only the most tenuous relation to health. The peer review system, which remains the best method of judging the quality of research projects, nevertheless places the decision about relevance in the hands of those least likely to make hard judgments on the subject, namely, the most prestigious and successful professors of biological sciences.

Nevertheless, money can do some good if it is applied carefully. There are a number of scientists in Private and Autonomous State Universities who would carry out agricultural research if they had the funds to do so. Moreover, this research is often in areas that agricultural scientists are too preoccupied to be able to explore. For example, Departments of Weed Science are virtually entirely occupied with herbicide research and do not have the opportunity to study the community ecology of weeds, their insect pests and the cultivated crop as a system. There are scientists at Cornell, Michigan and Harvard, to name only three, who would be delighted to study the ecology of weeds in cultivated fields with the direct interest of production in mind. The same is true in entomology, where the possibilities of ants as controllers of pest insects are still untapped.

An expanded Competitive Grants Program in agriculture would be very helpful in funding such projects and perhaps in beginning to give legitimacy to agricultural research in the Private and Autonomous State Universities. Such a program should be in the hands of a peer review system made up of a) scientists from the Private and Autonomous State Universities who have carried out research related to agriculture; b) scientists from substantive basic science disciplines who have not done agricultural research and c) agricultural research scientists (not basic scientists) from faculties of agriculture. No restriction as to research subject should be made, but money ought not to be given ordinarily to projects that would normally be fundable by NSF, NIH, DOE, DOD and other such agencies. Very large amounts of money can be usefully spent on agricultural research in non-agricultural research settings providing the criterion of relevance is enforced in spirit as well as in the letter.

Commissioned Paper VI

THE ROLE OF NON-LAND-GRANT UNIVERSITIES IN FOOD AND AGRICULTURAL RESEARCH

Charles M. Smallwood

Office of Technology Assessment

December, 1980

The term non-land-grant developed to characterize those institutions other than the 1862 and 1890 institutions belonging to the National Association of State Universities and Land Grant Colleges (NASULGC). The non-land-grant institutions are in reality public state universities belonging to the American Association of State Colleges and Universities having agriculture, forestry, and food-related programs (180 of 332 AASCU institutions in 29 states) (1).

Many of these institutions began as regional state colleges located in the agricultural regions of the states, 90 percent of those have developed into comprehensive multi-purpose institutions serving their region and state, graduating approximately 30 percent of the undergraduates in agriculture in the U.S. Approximately 25 percent of these institutions have graduate programs on the masters level and several have doctoral programs in agriculture and nutrition (2). This paper* will speak to the involvement of the 58 agriculture-forestry institutions** in research activities. One hundred twenty other institutions have nutrition and food-related programs--many with associated graduate and research entitites.

The AASCU Agricultural institutions are primarily teaching institutions, many of which are located in the important agricultural centers of their respective states and of our nation. After World War II, most of these institutions developed into multi-purpose institutions improving the quality of the faculty to the point that now approximately 68 percent of the more than 1,000 faculty in agriculture have doctorates (3,4). Almost without exception, these doctorates are from Land-Grant institutions.

These AASCU institutions perceive their roles as providing teaching, research and public service to their regions and states in accordance with guidelines set forth by state legislatures and/or Commissions of Higher Education. Many of these institutions have state-legislated responsibilities in the area of Food and Agriculture. Most have become involved in research during the last 30 years (4) as their faculty expertise improved and the institutions recognized a function they could perform with the agriculture of the region, various commodity groups and, in a few cases, with the USDA and/or Land-Grant universities. Table 1 summarizes the research appropriations and/or grants received in 1979-80 by 29 (50%) of the 58 AASCU agricultural institutions.

Table 1

Research Appropriations and/or Grants Received 1979-80*

Source of Funds	Amount	%
Amount from State Cooperative Land-Grant Institution	$ 292,000	2.5%
Other State Appropriations	3,693,170	30.4
U.S. Department of Agriculture	827,359	6.8
Other Federal Sources	2,544,643	21.3
Association/Commodity and Other Private Grants	4,783,646	39.0
	$ 12,140,818	100.0%

*Reported by 29 (50%) of the 58 AASCU-AAUAA institutions.

Fifty percent of the faculty at the AASCU Agricultural institutions are involved in research (3). Most of this research is applied in nature, some basic, secured from state and federal governments such as energy departments, competitive grants of USDA, USAID-BIFAC, NSF, commercial or commodity groups.

Some full-time research staff and/or centers have been developed in response to special needs (Table 2). California State University - Fresno has developed a Viticulture Research Center because 100% of the raisins grown in the U. S. are grown within 100 miles of Fresno. Arkansas State University - Jonesboro has developed special emphasis in soybean research and demonstrations; Southwestern Louisiana has special Horticulture and Crawfish research centers; Texas Tech University has a Beef Cattle Performance research center in the nation's fed-beef and processing area; Western Carolina has the Center for Improving Mountain Living and a broad range of programs concerning rural development. Many others could be cited, but research by faculty and the thrust has developed because of the interest of the faculty and institutions in serving, identifying a need, working with the industry, state and or commodity groups for funding. This funding ranges from $500,000 to $3,000,000 at institutions like Southern Illinois, Texas Tech, and California State University - Fresno, to a few thousand dollars at some institutions (4). Staffing will range from five to six full-time researchers to a faculty member teaching a 15-semester-hour load and doing research as an overload for nine months and full-time in the summer.

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*The views in this paper represent the consensus of the membership of the American Association of University Agricultural Administrators as conveyed to the author at the November 1980 annual meeting. Also in concurrence is the AASCU Agriculture, Natural Resource, Rural Development Committee.

** These universities are organized into the American Association of University Agricultural Administrators (AAUAA) and work closely with the AASCU Agriculture, Natural Resources, Rural Development Committee composed of presidents.

Table 2

Special Research Centers at AASCU-AAUAA Institutions
(Incomplete)

Institution	Facility/Project
Murray State University	Mid American Remote Sensing Center with NSAS Biological Research Station, Kentucky Lake
Texas A & I University	Citrus Research Center
University of Wisconsin, Platteville	Beef Testing Station
University of Wisconsin, River Falls	Center for Vocational Education in Agriculture
University of Wisconsin, Stevens Point	Summer Work Experience Field Camp
Illinois State University	Solar Energy Research (ISU-ERDA-NASA-GE)
West Texas State University	Kilgore Research Center Beef Research Station Wind Energy Involvement (State-Federal)
California State Polytechnic University, Pomona	Small Ruminants-Semen Research Center Equine Research Center
Western Carolina University	Center for Improving Mountain Living
California Polytechnic State University, San Luis Obispo	Beef Evaluation Center Solar Energy Industrial Dehydration Unit (Department of Energy)
California State University, Fresno	Enology Unit Viticulture Research Center Irrigation Technology Center
Southwest Louisiana University	Ira Nelson Horticulture Center Greenhouse Vegetable Research Center Crawfish Research Center Cooperative Weed Research Center
Texas Tech University	PanTec Research Center Textile Research Center International Center for Arid/Semi-Arid Lands (ICASAL)
University of Arkansas, Monticello	Beef Performance Station Research and Extension Center (cooperation with University of Arkansas)

Some specific research projects in which AASCU Agriculture institutions are involved develop from faculty interests and the interests of research committees of commodity boards such as cattle feeder associations, the Raisin Advisory Board, grain associations, irrigation associations, etc. Others develop from commercial concerns who need efficacy and field trials for products they are developing. Some projects are regionally and/or commodity oriented. Most of these faculty spend one-quarter of their nine-month appointment and/or the summers involved in research. Approximately 130 science man-years are contributed annually in agricultural research activity at AASCU Agricultural institutions (4).

Since producers (commodity groups and industry) propose projects or entities accept proposals (NST, competitive grants, etc.) from institutions, the priorities are set by the funding organization or agency either by the selection process or in mission-oriented projects. In some instances of state or university system fundings, the faculty member sets the priority and competes with other faculty for the funding on a merit basis.

Most projects conducted by AASCU Agricultural faculty have been proposed and/or reviewed by a research committee of a commodity group and/or reviewed by a special projects or research committee at the institution.

Some of these projects are reported in the CRIS system of the USDA. Some results are published in scientific journals, a few published jointly with the USDA and/or State Land Grant University Extension.

Producer groups generally have excellent input into research done at AASCU Agricultural institutions. The scientists work with them in setting priorities and designing research projects within the capabilities of the faculty members and institutions. Information is desseminated through field days, association meetings, agricultural sections of newspapers and to some extent through normal scientific publications. In many instances, results of research conducted at AASCU Agricultural institutions reaches the producer and public faster than federal or land-grant research results do. This is because the faculty are not involved in multi-faceted projects, and meetings or field days are conducted periodically for the producers with whom they are directly working.

The consuming public has very little input into research priority settings at AASCU Agricultural institutions since the research is producer or commercially sponsored and oriented.

Generally, there has been little coordination between AASCU Agricultural institutions and the State Land Grant Research systems, the USDA's Cooperative Research (CR) and Agricultural Research (AR).

There are exceptions and models exist for cooperation and coordination with these agencies. The Universities of Arkansas and Wisconsin have cooperative agreements with some of the AASCU Agricultural institutions in their states which enhances their service to the people.

AR and the Forest Service have cooperative agreements with a few state universities involving land, faculty, and/or funded projects. Some of these have been in existence for over 30 years, most are recent.

Several other institutional agreements exist between individual AASCU and Land-Grant institutions for research and joint appointments. However, generally, the AASCU Agricultural institutions have been ignored in planning and executing the research effort in the state and nation. Research and extension centers have been constructed and staffed adjacent to regional institutions that have PhD-level faculty. Staff for special missions and studies have been added to Land-Grant university entitities when regional AASCU institutions could have cooperated in their region or state-wide.

The primary deterrent to cooperation between the AASCU and Land-Grant institutions as well as the federal agencies has been a lack of a format for exchanging information, planning, and communicating. This improved with the passage of the Food and Agriculture Act of 1977, expecially Title XIV (5). Non-land-grant (other public universities) are written in the law to be included in the Joint Council for Food and Agriculture and have been included on national and regional planning committees. This is the first time most AASCU Agricultural institutions have had substantive interface with the USDA and Land-Grant research systems. Progress is being made in accordance with Section 1407 where the Joint Council's responsibilities "shall also be to a)provide a forum for the interchange of information among the organizations represented by the members of the Joint Council that will assure improved awareness among these organizations concerning the agricultural research, extension, and teaching programs, results, and directions of each organization" (5).

This progress is slow and the primary emphasis continues to be the research and related activities through the land-grant system. It appears that now is the time to give appropriate attention to "other public universities" to make effective use of all agricultural expertise.

There are several opportunities to improve the involvement of AASCU-AAUAA institutions:

1. Make minor adjustments in the 1977 Farm Bill and renew the legislation for five more years.

2. Continue to implement Section 1407 which fosters coordination and an interchange of information among those in the food and agriculture community.

3. Secure funding for the Higher Education component of the Science and Education Administration so both NASULGC and AASCU-AAUAA can provide feedback on enrollments, faculty, research, career placement and manpower assessment.

4. Include "non-land grants" in such national inventories as research facilities, capabilities and potential.

5. Expand the fundings for Competitive Research Grants for eligible institutions and fund Section 1417 for educational competitive grants.

6. Foster activities on the national level that encourage cooperation between land-grant, USDA and other public universities. One thousand PhD's, the majority of whom are on nine-month contracts, and specialized research entities could be utilized by states and the USDA. If they were recognized as an untapped potential resource and fostered, the research and service thrust of this nation could be expanded very economically.

7. Encourage states to foster coordination among the land-grant and non-land-grant institutions of the state. These number from one to as many as 9 four-year baccalaureate-level institutions in the states.

8. Expand the recognition of AASCU-AAUAA institutions on the national level, as significant contributors to the educational research and service activities related to the food and agriculture chain in America.

9. Include the AASCU institutions who have agriculture, food and nutrition programs in planning the national Human Nutrition thrust. Many of the finest programs in the nation are located at these institutions. Valuable mission-oriented mini-centers for human nutrition could be economically developed.

It should be noted that none of these recommendations diminishes the role of the land-grant universities or the USDA. On the contrary, it expands their role as cooperators in the area of food and agriculture and encompasses a significant contributor which has heretofore been ignored.

It is apparent that if all of the resources the U.S. are to be mobilized to develop the best research and service network to serve the interest of this nation in food and agriculture, the resources of the "non-land-grant" food and agricultural universities will need to be utilized.

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Commissioned Paper VII

POST-HARVEST TECHNOLOGY RESEARCH

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Office of Technology Assessment
U.S. Food and Agricultural Research
Work Group II

Paper #7

September 1981

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SUMMARY

This report deals with research in post harvest technology (PHT). Post harvest technology is defined to include all processing, preserving, and marketing activities in the post harvest sector; both technical and economic aspects of marketing are included in this definition. It is concerned with the physical and biological functions involved in assembling, processing, fabricating, preserving, packaging, storing, and transporting agricultural commodities with the purpose of transforming them into attractive, safe, high quality consumer products with minimum losses in market channels. Post harvest technology is also concerned with the economics of supply and demand, resource allocation, financing, revenue flows, exchange systems, price discovery, market structure, market performance, market efficiency, and issues of equity, policy, and environmental quality. Post harvest technology embraces all activities for all agricultural commodities* from harvest to consumer purchase.

This report addresses the interests of many concerning the relative roles of the public and private participants in PHT, how their research activities should be articulated and the extent to which the Federal Government should continue to support such research. Some criticisms are advanced, conclusions drawn, and suggestions offered.

The report concludes that public, and especially Federal, support of PHT research is in the public interest and contributes to the well-being of the people of the United States, individually and collectively. Most activities related to food and agriculture are off-farm activities, and a large fraction of the food supply is now marketed in processed form. The component of agricultural research that deals with the problems of this sector--research in PHT--is grossly underfunded. Because more than 60% of the ultimate value of food products is created after the products leave the farm, research on post harvest activities offers the greatest potential for reducing costs and alleviating the relentless upward pressure on the consumer's food bill.

This conclusion recognizes and is based on the dual role of Government in maintaining a free and competitive economic system and, simultaneously, of enhancing the well-being of the populace it serves. Research results and technologies emanating from the public agricultural institutions, the U.S. Department of

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*Consideration of forestry, wood products, and human nutrition is not included for the purpose of this report.

Agriculture (USDA) and the State Agricultural Experiment Stations (SAES), are freely available to all potential users. Conversely, research results and technologies generated in the private sector are highly privileged and are withheld from competitors, thus creating and perpetuating an inefficient situation in which several firms must replicate research and development efforts and costs in order to remain competitive. Market structures that depart from the tenets of pure competition are conducive to the extraction of monopoly profits--i.e., they unduly enhance consumer food prices. Moreover, private firms are more likely to engage in research as the market structure approaches pure monopoly and on research and development that has the potential for early profit. Societal issues such as health, nutrition, food safety, the environment, and researches of a basic nature are not likely to be among the first to which private firms will devote their resources. Government, representing the public, has few means to persuade private industry to do research that is primarily in the public interest and must bear the major responsibility and cost of performing it. Because the consumer is the ultimate and major beneficiary of research and development and because food commodities flow freely in interstate commerce, equity is clearly favored by Federal Government rather than State Government support.

Handlers, processors, fabricators, transporters, retailers, and others in the private sector are the direct users of the results of PHT research. The practical aspects of product development, modification, and improvement, including preservation and packaging, are largely the province of private firms and are facilitated by their own research results and those flowing from USDA and other public institutions. A logical and traditional division of effort between the public and private institutions is to give major emphasis to research, particularly basic research, in those that are public and to applied research and development in those that are private. This ensures attention to such issues as food safety and quality, nutritional requirements, and environmental quality which are not likely to be addressed by the private sector because of the absence of profit incentive. A viable PHT research program in the public sector (USDA and SAES) also contributes to maintaining a competitive market structure with most of the gains due to improved efficiency flowing to consumers.

In its six sections, the report addresses the genesis, growth, and development of PHT research in the American food and agriculture industry, how the effort has been shared and some of its accomplishments; traces the history of investment in PHT research by source of funds and performers; identifies the beneficiaries of PHT research and describes how research results are utilized by them; considers the articulation of USDA, SAES, and private institutions in PHT research--basic, applied, and developmental--and some of the problems that have arisen; makes observations on methods of evaluating the quality of PHT research; and discusses PHT research potential and the level of support suggested for it during the 1980's and beyond.

Section One

Development of Post Harvest Technology Research in U.S. Agriculture and Some of its Accomplishments

Physical or biological research on preventing losses of perishable crops and seeking new markets started in the early days of USDA and SAES in the latter half of the 19th century. As agriculture grew and perishable crops such as fruits and vegetables were produced a long distance from markets, research on handling, transportation, and storage became important and, as a result, many improvements were made in the marketing of these crops. Examples include: determining the storage requirements for horticultural crops; identifying and controlling market diseases; improving refrigerated transport; developing controlled atmosphere storage of apples; finding maturity indexes for fruits; developing nondestructive methods for determining quality; and accumulating basic information on the post harvest physiology of fruits and vegetables.

With increasing urbanization and increasing numbers of women working away from home, changes took place in eating habits. Food processing grew into an important industry. The physical and biological research programs of the USDA and the SAES, augmented by the establishment of the regional utilization research and development laboratories in USDA, kept pace and led the way in innovation. Examples of research accomplishments in USDA and SAES include: development, with industry, of frozen citrus concentrates; determining the time-temperature tolerances of frozen fruits and vegetables; accumulating basic information regarding the technology of food dehydration; development of potato flakes; effecting improved flavor stability of soybean oil. development of processes for using American soybeans in the preparation of Oriental foods, thus preserving the export market and establishing a new American market for soybeans; development of xanthan polymer as a new texturizing ingredient for processed food; development of methods for protecting food and feed from mycotoxins; development of durable press cotton fabrics; improving processing techniques for cotton mills and improved practices for cotton ginning; effecting a number of improvements in the marketing of potatoes; producing sterile fluid milk; and improving the deboning of meat.

Not all PHT research conducted by USDA or SAES and having potential commercial applications has been adopted by industry, although some may reasonably be expected to be commercialized in the near future. Adoption of research developments depends on such factors as the cost of energy or petrochemical raw materials, amortization of equipment used in present processing methods, or market potential of the product. Examples of PHT research not commercialized to date are: a process for the fractionation of tallow that yields higher-valued fractions; a process for recovering food grade protein from alfalfa; a borax-based finish that imparts a high degree of smolder resistance to cotton upholstery fabrics; bisulfite preservation of fresh hides to replace the present brining method and associated salt pollution problems; starch derivatives as encapsulating agents for herbicides that improve the efficacy of weed control, reduce environmental pollution and hazard to farm workers; biodegradable starch-based mulches for vegetable crops; new crops as sources of raw materials for industrial chemicals and pulps for paper products; methods for doubling the storage life of fresh peaches and nectarines; and an experimental van container that is superior to conventional containers for the refrigerated shipment of perishables.

Economic issues in marketing were given little attention until after World War I, when it became evident that the capacity of American agriculture to produce had grown beyond the capacity of the domestic and foreign markets to consume the products, except in time of war or in periods of adverse weather. The Research and Marketing Act of 1946 provided the first major stimulus for economic research in the post harvest sector and provided additional support for research in the biological and physical aspects of marketing as well. Marketing research grew during the following two decades, and Economics Departments with emphasis on marketing emerged as full complements of most agricultural colleges and experiment stations.

Since 1965, there has been diminished emphasis on all aspects of PHT research. This period of waning support has coincided with rapidly rising prices at the consumer level. With adequate support, PHT research can, as its record demonstrates, contribute significantly to moving the National economy in a more favorable direction.

Section Two

Investment in PHT Research and Funding Trends in the National, State, and Private Sectors

Value added in the ag-food post harvest marketing sector in the United States increased from $60.0 billion in 1966 to $69.9 billion real dollars in 1979, an increase of about 16%. In 1979, this post harvest sector comprised about two-thirds of the total ag-food industry, reflecting that most of the activity related to food and agriculture is now off-farm, and that a large portion of the food supply now moves through commercial channels in processed* form with highly processed convenience foods an important factor. Contrary to this significant trend in the ag-food industry, total funding of PHT research has not only not increased commensurately, but has failed to maintain the real dollar level that prevailed a decade ago, suffering a decrease of 1.5%. Federal in-house PHT research, principally that in ARS and ERS has quite obviously been deemphasized by USDA budget makers during the past decade, declining 16% between 1966 and 1979.

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* Includes such "processing" as washing, trimming, and packaging of fresh fruits and vegetables.

Waning Federal support of PHT research has been partially offset by state support which increased 62% between 1966 and 1979. Private firms also invest in research and development related to food and kindred products. Individual states support PHT research in order to enhance or maintain the competitive position of the individual state in national and international markets. Private firms engage in PHT research to enhance or maintain the position of the individual firm in the market. Conversely, Federally supported research is done in the public interest more readily and usually more quickly redounds to the advantage of all consumers.

Section Three

Beneficiaries of PHT Research

It is the role of government to promote competition and encourage economic development, and this insures a rising level of affluence in the populace it serves. Economic development can best be encouraged through research and education, since new, modified, and more efficient technologies stem from research and the dissemination of research results. Under a policy of free trade among our fifty states, the responsibility for maintaining a competitive economic environment and fostering economic development falls primarily on the Federal Government.

In a competitive economic environment, benefits from PHT research accrue largely to consumers. As food and kindred products flow freely interstate, so do the benefits of PHT research. Thus, it is apparent that equity will be best under total Federal funding of PHT research where all of the people share the cost.

Rising affluence of the people is achieved largely through increasing labor efficiency. While most technical innovations are designed to increase labor efficiency, those that make possible the substitution of energy and capital (machines) for physical labor make the primary contribution to labor efficiency and rising affluence of the people.

During the decade 1970-79 and continuing into the 1980's, the process of increasing energy and capital inputs is being thwarted by rising prices of energy and escalating interest rates.

High interest rates on borrowed investment funds discourage plant conversion to adopt more labor-efficient innovations, thus delaying adopting and eroding the benefits of PHT research. For these reasons, those involved in PHT cannot afford to neglect research that contributes to the search for alternate sources of liquid fuels and technologies that utilize other forms of energy.

Commercialization of PHT research developments may, in some instances, have short-term adverse effects as it does when the introduction of labor-saving equipment displaces labor, requiring its relocation. New product development, although beneficial to the consumer and some segments of the economy, may have adverse effects on others as the development of margarine had on the dairy industry. But the commercialization of margarine provided new jobs in margarine plants and a new cash oilseed crop for the Midwest and South. Similar effects may be anticipated as acceptable meat and milk analogs are developed from vegetable proteins and fats. The impact of these potential developments will depend on the supply-demand situation for meat and milk, when and if the analogs become available. Environmental pollution problems, sometimes associated with ag-food processing plants, are disadvantageous to some until research creates new technologies that reduce or eliminate them.

It is concluded that although short-term disadvantages may spring from some applications of PHT research, they are far outweighed by long-term benefits.

Section Four

The Role of the Public and Private Participants in PHT Research in Retrospect and Prospect

The roles of the primary participants in PHT research--USDA, SAES, and private industry--and their relationships have developed over more than a century without concerted attempt to define or alter roles to assure better articulation of the several parts. For a large part of their history, each has financed and done research on the commodities or products and the problems associated with them, that best suited its interests--USDA principally on problems of national or regional impact, the SAES on those of primary interest to the people of the State, private industry on whatever seemed destined to be profitable. From the beginning until the present, the roles of each public performer in PHT research--who finances it and who performs it--have been determined by ad hoc agreement between the parties concerned. The staff and paperwork requirements for accomplishing this have become large and cumberson.

It is concluded that it is appropriate for all three of the primary participants to continue to support a share of PHT research and, since all of the people in the United States benefit from most PHT developments, the USDA should continue to bear the major responsibility for financing the public share. It is also concluded that the role of the performers and distribution of the workload among them has historic precedent and still appears sound today.

It is proposed that: PHT research expenditures by each participant should be in proportion to the benefits each expects to derive; PHT research should be performed where the staff and facilities are best suited to the job. Existing USDA staffs and procedures could be re-oriented to undertake determining who is likely to benefit most from proposed research and the location of unique competence and facilities for performing the research. While a system so based might be no less complex than the existing one, its adoption and refinement could help clarify some long-standing areas of confusion between USDA and the SAES with respect to funding and programming.

Observations are made as to where the emphasis on basic, applied, and development research should be and what it takes to establish a favorable climate for research. A case is also made for maintaining strong research programs in USDA. In this connection, organizational and managerial changes made over the past decade are believed to have created a less favorable climate for PHT research in USDA, and a greater need for elaborate staff work. Federal-State relationships during this period have not improved perceptibly. It is too early to evaluate the reorganization of 1981.

Section Five

Methods for Evaluating the Quality of PHT Research

The ultimate value of research and development is the performance of the sector to which these activities are directed. By this measure, agricultural research, including PHT research, has been outstandingly successful. The agriculture-food industry system has provided an abundance of high-quality food to the American public at the lowest percentage expenditure of average income of any country in the world. There are, however, outputs of research other than the economic value of the ultimate products or process to which it leads that are less easily measured, yet may have great social benefit. For example, does it prolong or save lives or eliminate pain or discomfort? Does it eliminate or modify onerous labor? Does it save time? Does it minimize waste? Does it avoid pollution? Many of the developments of PHT research have one or more of these attributes.

The quality of basic research and mission-oriented disciplinary research, which characterize much of agriculture-food research, is difficult to measure in terms of economic value since applied and developmental research and considerable elapsed time, generally separate it from a tangible result, e.g., a product or process. Other measures of quality of research have been suggested. B.T. Shaw proposed to evaluate the quality of USDA scientific publications by a peer group ranking based on their impact on science, agriculture, and general welfare. Of the 105 publications ranked by a peer group as having limited to very great impact, one-third were in the area of PHT research. One-half of those ranked as having great to very great impact also were in the area of PHT research. During the period of these accomplishments, PHT research never enjoyed funding greater than 25% of the total for research.

Evenson and Wright compared the quality of publications of SAES and USDA PHT research project leaders on the basis of the number of times their publications were cited in peer-reviewed journal articles. Statistical analyses of the difference showed no difference. A more comprehensive comparison of citations of USDA Regional Research Center articles published in peer-reviewed journals in 1966 and 1978, indicated no decrease in high-quality research per scientific-man-year over that 12-year period. A similar comparison of citations of PHT patents issued to private industry and the USDA Regional Research Centers indicated that PHT patents of the latter were a significant part of the invention structure of the private sector.

A generally accepted method for evaluating the quality of research has yet to be devised.

Section Six

Future Potential for PHT Research and Proposed Level of Support

PHT research has not fared well with the decision-makers in recent years as emphasis has shifted to issues of energy and natural resources conservation, plant biology, environment, and nutrition. These are important issues. However, development of new and more efficient methods for processing, preservation, and distributing foods and kindred products (the domain of PHT) is as vital to the welfare of American consumers.

There is great potential, for example, in developing sound and consumer acceptable high-protein foods directly from plant sources thereby conserving energy, water, and soil. Increased labor efficiency in the marketing sector also offers great potential for reducing the relentless upward pressure on costs of food and kindred products. Agricultural raw materials, including crop residues and new crops, offer many opportunities for supplementing or replacing petrochemicals as industrial raw materials.

The level of PHT research needed to secure optimum returns cannot be determined with precision since so many of the benefits of such research can only be measured subjectively and defy quantitation. Nevertheless, it is vital that convincing evidence in support of funding needs to be developed regularly as part of the budgeting process. Without such convincing evidence PHT research may appear less compelling than other activities competing for a share of national and state budgets. Essentially, the optimum level of support of PHT research is a matter of judgment on the part of appropriating bodies making it imperative that they be adequately informed and advised. Such information and advice should come from professional personnel and their administrators since they are in the best position to determine what the research objectives should be and the nature and size of the research program needed to achieve them. These people should have the fullest possible grasp of the relative urgency of problems in the wide field of PHT research and a keen sense of timing as to when shifts in program emphasis can be most productive.

The history of the past decade or two reveals that, as a proportion of the total Federal research expenditures for ag-food research, PHT research ranged from 32% in 1966 to 26% in 1979. Corresponding figures for the SAES were 17% and 15%. One might argue that the percentage of the total public funding of PHT research should be considerably greater than this, perhaps as much as 60% of the total since this is the value created in the ag-food sector attributable to the off-farm activities toward which PHT research is directed. However, in view of the many variables that must be considered in the annual budgeting process, it is more realistic to suggest only that Federal PHT research funding should be much higher than it is. Existing Federal facilities, and perhaps those in some of the SAES could accommodate additional research with excellent potential for significant returns.

INTRODUCTION

Inasmuch as the support of PHT research and development in the private sector on food and kindred* products has increased in recent years, it is understandable that the Congress would be interested in the extent to which it should continue to support research of this nature. This paper addresses that issue in considerable detail, but first, as necessary background, PHT research is defined, some general observations on the responsibilities of government and private industry are made, and some of the critical issues that affect food and agriculture today are noted. All of these have important bearing on the question of government support of research in post harvest technology.

Definition of PHT

The phrase post harvest technology in agriculture is meant to include all of the technological and economic manipulations a crop undergoes between harvest and the kitchen. Thus, PHT research involves the physical and biological study of the functions involved in assembling, processing, fabricating, preserving, packaging, storing, and transporting agricultural commodities and food products. It also involves the economics of supply and demand, resource allocation, financing, revenue flows, exchange systems, price discovery, market structure, market performance, market efficiency, and issues of equity, policy, and environmental quality. For purposes of this report, PHT research on forestry products and human nutrition is excluded.

Some Important Functions of Government

The Federal Government has a major responsibility for maintaining a free enterprise system. Such a system requires protection against monopolistic practices designed to thwart competition. Monopolistic activities may stem from both domestic and alien sources. Our government, or any government, has very little power to counteract alien monopoly such as that manifested by the OPEC oil cartel. Monopolization of crude oil supplies on a worldwide scale has also demonstrated the adverse economic impacts of such activities, and the ensuing maladjustments throughout the economic system, including rapidly escalating price inflation and periodic high levels of unemployment. On the domestic front, the government does have the power and the responsibility to counteract monopolistic forces. Various antitrust laws provide the authority and various departments and agencies provide the mechanisms to regulate or referee the market exchange system.

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*Kindred products include natural fiber, wood products, tobacco, alcohols, and other products of an organic origin except those derived from fossil fuels.

Government also has the responsibility to enhance the productivity of the populace which it serves, and provide a climate favorable for economic development and social tranquility, that is, a society relatively free of agitation and disturbances such as domestic crime and external duress. Economic development depends heavily on technical innovation which evolves from research and education.

A basic tenet of good government, however, is that it should not do what a socio-economic system will do for itself. In other words, government should not do what the private sector can or will do. Nevertheless, this tenet has to be balanced against the inherent tendency of the private sector to become more and more engaged in research and development as it becomes more monopolistic in character -- the fewer the firms in a particular sector of the economy, the more likely it is that they will be involved in research and development. It must also be recognized that government, except for the research and development it purchases, has no power to mandate research and development in the private sector nor to direct or even influence the nature of such research. Thus, if serving the "public interest" is paramount, the government should not hastily abdicate its responsibilities. The "public interest" in food and kindred products embraces such attributes as efficiency, adequacy of supply, low cost, equity, safety, and contributions to health and well-being. The public also expects the production of such products to be consistent with a relatively clean environment.

Federal/State/Private Agricultural Research

In the agrarian society that persisted even into the 20th century in the United States, there was very little agricultural research in the public sector. However, in the third quarter of the 19th century, the Federal Government established and fostered a system of agricultural and mechanical colleges, State Experiment Stations, and research agencies in the Department of Agriculture, and there developed a partnership which both State and Federal Governments have never ceased to support.

As the agriculture-food system became progressively more specialized, the private sector became aware of the advantages of doing its own research and development. Private industry became involved in mechanization; seed and feed companies began research in crop breeding and animal nutrition; chemical companies initiated research on plant nutrition and pesticides; private interest grew in research on food processing, development of new and modified foods, transportation, warehousing, wholesaling, and retailing. As this trend continued, and even as late as the first quarter of the 20th century, the production of American food and kindred products was characterized by nearly pure competition. No one person, firm, or collation of firms had any control over aggregate supplies or market prices. However, it is apparent in recent years that the food and kindred products sector is becoming progressively more monopsonistic-monopolistic in character and some firms or collations of firms have gained some degree of control over supplies and some power in pricing. In most cases their economic power is far short of pure monopoly-monopsony but their existence causes the system to depart substantially from one characterized by pure competition.

Private vs Public Support of Research

Most of the research and development conducted by private firms is designed to enhance their profit potential. Moreover, much of the economic power of private firms is derived from the privileged technical developments that result. Each innovator gains some economic leverage which is retained until the innovation is duplicated by others.

Conversely, scientific information and technical developments stemming from publicly supported research is not privileged information, but is available to all would-be users. Thus, publicly supported research not only enhances productivity but contributes to maintaining a relatively competitive economic system, in contrast to privately supported research which has the potential for creating monopoly profits.

Thus, if government is to fulfill its dual role of maintaining a relatively free and competitive economic system and promote and foster economic productivity, then it is appropriate and necessary for government to support research related to the food and kindred products. Concommitantly, it is the responsibility of government to disseminate the results of research widely throughout the populace it serves.

Because food and kindred commodities flow freely in interstate commerce and benefits thus accrue to all of the people, research support is primarily the responsibility of the Federal Government. Federal support of research in food and kindred products assures equity in the distribution of benefits as related to support. It is recognized, of course, that some benefits of research flow to foreign consumers. Because the United States is a net exporter of food commodities, it is also likely a net exporter of benefits derived from research (both public and private) on food and kindred products.

Factors Influencing Food Price Inflation; Some Counter-Inflationary Factors

As the 1980's unfold, escalating price inflation in goods and services runs neck and neck with the USSR in contributing to apprehension in America. Although the fraction of income spent for food still remains low and steady, escalating prices in the food sector are especially critical for the future since nearly all the population is dependent on commercial food supplies.

Several factors have significant influence on inflation of prices of food agricultural products:

> ...such government activity as excessive regulation inhibits productivity, thwarts incentive, and contributes to price inflation.
>
> ...weather and pest-related shortfalls in crop and animal production contribute to inflation in food prices because the pricing mechanism is used as a means for allocating or distributing the available supply of food and kindred products among the people.
>
> ...escalating wages and salaries for personal services relative to labor productivity; wages and salaries cannot rise faster relative to labor productivity without creating inflationary pressures.
>
> ...monopolistic power, that is, exercise of any degree of influence to enhance prices (including wages and salaries) such as the activities of OPEC during the past decade, as well as some activities of labor unions and of those who administer wages and salaries, including those in the public service, and of any business or industrial firm or collation of firms that has the power to set prices and make them stick. None of these, with the possible exception of OPEC, approach pure monopoly but they represent rather substantial departures from pure competition. In a purely competitive environment, most of the benefits of a progressive economy would be manifested in falling prices of goods and services which obviously does not characterize the state of the USA economy in the 1980's.
>
> ...the availability of capital (investment funds) only at excessively high interest costs which prevents implementation of new technology as it comes on stream and subsequently retards the improvement of labor productivity. Excessively high interest on borrowed funds suppresses especially the young innovators, those with initiative and ideas but with limited capital.

There are also several factors that have significant counter-inflationary influences on inflation of the prices of food and agricultural products:

...such government activities as storage programs, and the building of interstate highways and waterways.

...research to find means to alleviate or circumvent the effects of adverse weather and pests.

...research directed toward improving labor productivity.

It is noteworthy, despite this important counter inflationary potential of research, including PHT research, on curbing escalating inflation, there has been diminishing public support of PHT research in recent years.

Other Issues Related to PHT

While inflation is the burning issue at present, there are other issues that also have important bearing on need for and level of public support of research in post harvest technology. Among the issues are food safety, food adequacy, environmental quality, alternate sources of liquid fuels and chemicals, equity among participants in the food-agriculture system, and urban vulnerability to malfunctions in food distribution. Several of these issues are discussed later in this report.

Section One

DEVELOPMENT OF POST HARVEST TECHNOLOGY RESEARCH IN U.S. AGRICULTURE AND SOME OF ITS ACCOMPLISHMENTS

What we now regard as research in post harvest technology, embracing as it does the myriad physical, biological, and engineering transformations and modifications that agricultural commodities undergo in becoming food, as well as the multitude of economic operations between the farm and the consumer, evolved as increasing specialization in the agriculture-food industry made it necessary. In addition, research in PHT contributed much itself to increasing specialization in that sector of economy. Basically, biological and physical research in PHT is concerned with transformation of primary commodities into attractive and acceptable consumer products and includes protecting the quality of fresh products, reducing losses in marketing channels, ensuring quality and safety of processed products, and improving nutritive value. These steps are desirable because consumer requirements for food are rather constant throughout the year while harvests are seasonal. Processed foods that are stable and transportable without loss of quality have also become necessary now that the locations of crop production are remote from population centers, and food must often be transported over long distances and stored for protracted periods. Post harvest technology research innovates and contributes to efficiency throughout the process.

Similarly, the economic research segment of PHT focuses on the efficiency of the exchange system between farm crops and food and in the distribution of the revenue derived from the final purchaser (consumer). It is also concerned with efficient allocation of resources in primary production and in marketing, with pricing efficiency, with revenue flows which involve issues of market organization and structure, and with efficient financing, and accurate monitoring and forecasting of markets.

A high degree of specialization and attendant efficiencies in production and marketing requires an efficient exchange system. Rising affluence is dependent on specialization and specialization is dependent on market exchange. Thus, research is directed to both physical and economic efficiency in the post harvest sector, and translates into an increased quantity of higher quality food at the consumer level with attendant prices lower than would exist in a less efficient system.

The following paragraphs trace the cardinal aspects of the rise and development of the above kinds of physical, biological, and economic research, in other words PHT research, in U.S. agriculture.

Research in Handling, Transportation, and Storage of Agricultural Commodities

This aspect of post harvest technology research has been part of the research interests of the USDA and the SAES since the beginnings of both in the latter half of the 19th century. As early as 1867, the Commissioner of Agriculture's annual report called attention to the possibility of improving the marketing of oranges by wrapping the fruit in paper wrappers and packing it in wooden boxes, a practice followed by Italian producers. The fruit was reported to arrive in the market in perfect condition after a 3-week voyage. The Commissioner's report of 1886 cited the overproduction of fruits, stating that they were overabundant enough to tax the powers of home consumption and pointing to the need for methods for handling such surpluses to avoid waste. Also in 1886, funds were appropriated to hire a mycologist to study the diseases of fruits as well as plants. The American Pomological Society, meeting that year, passed a resolution commending the action and assuring support, and the Western New York Horticultural Society and the Botanical Club of the American Association for the Advancement of Science took similar action (1). This was the beginning of studies in the USDA on diseases that attack fruits and vegetables and cause losses during marketing.

The USDA reached Cabinet status in 1899, and the Department had then some $2 million for research, compared with $8 million in France, $4 million in Austria, and $2.85 million in Germany. It was also engaged in planning an exhibit of horticultural products for the Paris Exhibition of that year. Apples and oranges were to be prominent in the fresh fruits since it was hoped to find new markets for them in foreign countries. Working with the fruit industry, the USDA arranged for successive shipments of fruits from the 1900 crop as it matured. Cold storages were arranged for in New York and LeHavre, France. A refrigerated compartment in an ocean steamer was secured. No other country, not even France, attempted to keep a display of fresh fruit during the entire period of the exhibit.

The successful experience of Wm. A. Taylor, who was in charge of the exhibit, convinced him that if proper care was taken in selection and protection of the fruit during shipment, the marketing season could be prolonged and distant markets could be reached. Accordingly, with the creation of the Bureau of Plant Industry in 1901, systematic research began on the handling, transportation, and storage of fruits and vegetables. The Bureau was directed by the Secretary of Agriculture to investigate methods of harvesting, packing, storing, and shipping fruits and vegetables and to do research to improve markets in the United States and in foreign countries. Under the leadership of Wm. A. Taylor and later of G. Harold Powell, the investigations grew in importance and greatly improved the fruit and vegetable industry's capabilities for marketing the crop. The research also brought about improvements in refrigerator cars, cold storage plants and packing house practices for fruits and vegetables. In studies made on California oranges in 1904-1906, decay was found to be a serious problem in shipments to eastern markets and losses were estimated to amount to as much as $1 million per year. The investigations showed that the fruit was injured when it was clipped from the tree and that decay grew from the site of injury. Close supervision of picking and packing house practices to reduce mechanical damage, and doing a better job of refrigeration, reduced decay from about 17% to about 1%. The annual savings at that time were estimated to amount to about $250,000.

As the fruit and vegetable industry grew, new, more distant markets were reached and the handling, transportation, and storage studies were expanded. Field stations of USDA were opened in major production areas and cooperation with the SAES, where similar work had been initiated, became a matter of course. Laboratories were established in Chicago and New York, two major markets, where diseases causing losses in fruits and vegetables during shipment were studied. Work there and with the SAES resulted in the development of methods of prevention, and the scientists at these laboratories worked closely with officials of USDA's Inspection Service to organize and operate training courses for inspectors.

These studies, known as Handling, Transportation and Storage Investigations, continued in the Bureau of Plant Industry from the turn of the century until the early 1950's when the USDA was reorganized and the Bureaus were eliminated. Shortly before that reorganization, Congress, in 1946, enacted the Research and Marketing Act. The purpose of the Act was to focus renewed attention on and provide additional funds for marketing research, including a requirement that SAES devote a minimum percentage of their Federal resources to marketing research. At about that time there was concern that marketing research in USDA was too scattered to be properly administered and that some research in USDA that was not marketing research was being paid for out of Marketing Research funds. To help resolve these questions, the decision was made during the reorganization of the 1950's to bring the research together into a Marketing Research Division in the Agricultural Marketing Service (AMS). The Division included the Handling, Transportation and Storage Investigations of the Bureau of Plant Industry, the Stored Products Insects Research of the Bureau of Entomology, the Transportation and Facilities Studies of the Production and Marketing Administration (PMA), and studies formerly in the Bureau of Agricultural Economics concerned with Market Organization Costs, and Market Development. Some research scattered in other research Bureaus and in the commodity Divisions of AMS was also transferred to the new Marketing Research Division. There, for the first time, all research dealing with the marketing of agricultural crops was brought together under the leadership of Dr. Harry C. Trelogan. A close working relationship was established with the commodity Divisions of AMS, and their research needs were discussed, selected, and included in the research program, representing one of the strong points of the new organization. Another strong point was the opportunity provided for regular interchange of ideas and information between disciplines within the Marketing Research Division. Most of the State Experiment Stations had projects supported by Research and Marketing Funds and their research became part of the overall national USDA/SAES program of marketing research. Cooperation with industry, particularly to facilitate adoption of new developments, was widely practiced and effective. Programs grew in size and capabilities both inside and outside the Department and made significant contributions to the food and agricultural industry (see examples which follow and in the Appendix).

In the early 1960's, Marketing Research was transferred to the ARS, where it, utilization research development, human nutrition research, and other nonproduction research, formed a major part of the physical and biological part of PHT. Since then, particularly since the early 1970's, the research has been scattered into various parts of the USDA and support has waned. The overall objective of moving systematically and with determination to make the marketing system more efficient as was envisioned when the Research and Marketing Act was passed, appears to have been overlooked or lost even though marketing costs still absorb the largest part of the consumer's dollar.

Research in Industrial Utilization of Agricultural Commodities

In the early years of USDA, there were few commercially processed foods available to the American consumer. Major items were cured or salt-preserved meats and fish, cheese, crackers, cookies, and little else. Most Americans lived on the farm and raised much of their own food supply. The urban population depended largely on fruits, vegetables, and meats produced on farms within a relatively short distance of the cities. Food processing--brining, drying, canning--was done mainly in the home.

Today, less than 5% of Americans live on farms. With migration to the cities came the need to transport foods greater distances, and to develop new methods of food processing, preservation and marketing. Increased urbanization of the population, rise in per capita income, and the increased employment of women, has created an increased consumer demand for processed foods. Many steps, sometimes all, in the preparation of food formerly done in the home kitchen have been delegated to the food industry. For example, over half of all fruits and vegetables are purchased in processed form (2); more than 75% of the wheat flour milled is purchased as bread, bakery, or other processed forms (3); and about 70% of all sucrose consumed is purchased as an ingredient of a processed food (4). The consumer expects these foods to have fresh flavor, pleasing texture, and to be economical in cost. Fresh fruits and vegetables are expected to be "garden-fresh," picked at optimum maturity, and free from blemishes and insect attack. Nutritional value, health, and safety aspects of foods are additional consumer concerns that have come to the forefront in recent years.

To help solve particular aspects of many of the problems associated with these rather dramatic changes as they were occurring, the Congress had the foresight to expand the scope of the one-time Bureau of Chemistry in the late 1930's and gave it responsibility to research and develop new or improved industrial food and nonfood uses for agricultural commodities and their by-products (5). The renamed Bureau of Agricultural and Industrial Chemistry built, equipped, and staffed large laboratories (including pilot plants) located in the four regions of the country dedicated to these ends. In close cooperation with private industry and industrial associations, these laboratories devoted themselves to the creation of new food, fiber, and industrial products based on agricultural commodities as raw materials. This present part of PHT research, known for many years as utilization research and development, continues to make, despite waning support, significant contributions in making new or improved food products available and is creating new or improved cotton and wool fabrics and other nonfood products.

Research in the Economics of Marketing in Agriculture*

Marketing issues were of rather minor importance and received little research attention under the agrarian subsistence type of agriculture that persisted in the U.S. into the 20th century. The early emphasis was on self-sufficiency within rather narrow geographic limits.

However, agricultural mechanization and development of markets where farm products were assembled and sold, accompanied the industrial revolution of the 19th century. Water, transportation by the steamboat, followed by transportation by rail, made feasible the development of markets for farm products. The same transportation systems supplied the farmer with machines and other manufactured products in exchange for food, fiber, and other agricultural products.

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* This discussion is based partly on manuscripts provided by Dr. Paul L. Farris, Purdue University, for a book to be entitled "Future Frontiers in Agricultural Marketing Research"; partly on communications from personnel of the former Economic and Statistics Service, USDA; and partly on the experience of the authors.

As the manufacturing sector of the economy settled into structures that departed from the pure competition model, questions of equity evolved. The farm sector was characterized as price takers both of products sold to the industrial sector and for products purchased from it. Issues began to emerge with regard to marketing information (price, supply, export demand, etc.) available to farmers, market structure (competition) and efficiency of marketing functions.

Marketing problems began to receive research attention during the agricultural depression following World War I. It became evident that the capacity of American agriculture was growing at a rate exceeding that at which domestic and export markets were growing, except during times of war or adverse weather conditions.

The excess capacity of American agriculture was accentuated during the great depression of the 1930's, and agricultural research sought practical means for alleviating surplus problems. However, war once again in the 1940's swung the pendulum toward all out production and emphasis shifted from surplus disposal to concerns for an adequate supply of food and its preservation and distribution for both domestic and foreign needs.

The experiences in agriculture following World War I dominated the economic thinking as World War II was winding down. A major concern was that of developing products and markets to utilize fully the capacity of U.S. agriculture at prices deemed to be fair to farmers. Export markets in war ravished countries began to wane as production in those countries was resumed following cessation of hostilities. However, the rapid rise in American consumer affluence accompanied by an expanding demand for animal products was not fully anticipated, nor were the increased demands to be created by the Korean Conflict and the hot and cold wars that followed. This was the situation when the Research and Marketing Act of 1946 provided the first major stimulus for economic research in the post harvest subsector. Economics departments that emphasized marketing economics emerged as important components of most agricultural colleges and state agricultural experiment stations, and counterparts also emerged in the USDA. A part of the act that required a minimum percentage of Federal funds for ag-food research be spent for marketing research persisted until 1978.

Funds for research in marketing economics increased rather substantially in the period from about 1948 to 1965 but have remained nearly unchanged since then. The two decades following World War II coincided with the rapid commercialization of U.S. agriculture. By 1965, virtually all the food supply moved through commercial channels. The period 1948-1965 was also the era of proliferation of variety in foods available to nearly all consumers. Constraints in the realms of storage, transportation, distribution, and preservation were at minimum. Mechanical refrigeration, super highways, 18-wheelers, and abundant and cheap energy provided ready access to food from all quarters and in all seasons for virtually all consumers.

In the post-war period, economics research focused on issues of pricing efficiency, grades and standards, development and dissemination of market information, the changing consumer demand for specific foods, firm operating costs and efficiencies, development of export markets, and improving efficiency in exchange to provide the cash flow and other incentives necessary to activate primary production, assemble raw materials, fabricate foods, and store and distribute them over time and space in forms readily acceptable to consumers.

In the 1970's, rapidly rising prices at the consumer level were accompanied by periodic low prices to producers. The rising costs of food at the consumer level were attributed largely to rising costs of fuel and to declining labor efficiency accompanied by rising wages and salaries. In this critical period, support dwindled for marketing research.

Labor and energy efficiency in the food marketing subsector must have top priority on the research agenda of the 1980's. Unless efficiencies can be improved on both fronts and accompanied by constraints on wages, salaries, and fuel prices, there is no hope for alleviating the rentless upward surge in food prices that Americans have experienced since about 1972. The examples of successes in the paragraphs that follow demonstrate that properly supported PHT research can contribute significantly to finding practical solutions for these problems.

Selected Examples of PHT Research Developments Now Practiced Commercially

There follows a list of eight examples (with a score or two more in the Appendix) of PHT researches that have "paid-off"--that have improved marketing practices and/or enhanced supplies or quality of food and kindred products. Some are classics, some vintage examples, and some are of recent adoption by industry. As might be expected, many of the most recent developments are yet to be adopted by industry. Examples of these are given in the subsection that follows: In practically all, success was achieved through cooperation at some stage between the public participants (USDA/SAES) or collaboration between one or both of the public participants and a segment of private industry. Estimating the fraction of the credit due each participant involved in a collaborative development could be done by combing records to ascertain the expanditures of each over the period of investigation.

Post harvest treatments to control the diseases of fruit and vegetables after harvest have done much to reduce waste and spoilage. There are commercial treatments for most fruits and vegetables. They have been developed, for the most part, by Federal and State workers. Some have been the result of research in private industry, and in many cases, commercial companies have further developed what the government scientist has discovered. Without these treatments, there would be much heavier losses, which can be as high as 25 to 30% in commodities as perishable as strawberries. The effort now is to find treatments that do not leave chemical residues.

Controlled atmosphere (CA) storage, which means controlling the level of oxygen and carbon dioxide in the storage room, has changed the apple industry, making it possible to market a crisp, fresh-tasting apple over a longer season, almost the entire year (5a). Apple production increased 60% in the period 1967 to 1980. Along with this growth, the storage of apples in CA increased from about 13 million bushels in 1966, amounting to 21% of all cold storage holding, to about 45 million bushels in 1980 or about 42% of all apples stored (6). Annual return to the New York apple industry from this development is estimated to be $2,250,000, and $15 million in increased income annually to Washington State growers (7).

Frozen concentrated orange juice developed in the mid-1940's by USDA and Florida Citrus Commission researchers at USDA's Winter Haven, Florida, laboratory was the first processed product which brought the consumer the flavor and attractive appearance of the fresh orange juice (8-16). The product was commercialized almost immediately. In the 1979-1980 season, 175 million boxes of Florida oranges were used in the production of frozen concentrated orange juice representing about 85% of the season's crop (17). The availability of orange juice throughout the year in a form convenient to store and serve, made a significant contribution to the vitamin C intake of the U.S. population and provided an expanded market to the orange grower. Estimated cumulative farm sales of oranges due to the development exceed $6 billion (18).

Technology for food dehydration. Scientific investigations by USDA scientists and engineers during the early phases of World War II provided a rational basis for design of fruit and vegetable dehydrators and developed a technology for producing high-quality products which have since developed into substantial commercial markets (19). When the research was initiated, the U.S. effort for World War II required explosive growth in the capacity to produce dehydrated foods. In addition to advances in technological methods, Department scientists held workshops and conducted training programs for industry personnel to allow a rapid expansion in the business. The work was followed by further advances in drying technology by USDA scientists including the development of dehydrofreezing (20), belt trough drying (21), foam mat drying (22), and osmovac drying (23). The annual value of dehydrated products related to those developments was conservatively estimated to exceed $1.4 billion in 1970 (24). At current prices and production levels, the figure may be $3-4 billion annually.

Improved flavor stability of soybean oil. Soybean oil has become the most widely used vegetable oil in the United States. Production is approximately 12 billion pounds annually (25). More soybean oil is consumed each year in the U.S. than the total of all other food fats and oils. To achieve this degree of consumer acceptance, it was necessary to reduce the tendency of soybean oil to develop undesirable flavors and odors during storage, even for short periods of time. USDA scientists found the cause and played a leading role in a cooperative study with industry that showed how to improve flavor stability by use of citric acid to inactivate traces of metallic impurities (26, 27). They pioneered the use of the taste panel procedures for measuring flavor (28, 29). Since then, USDA scientists discovered other inactivators, developed improved methods for avoiding off-flavor, and found better materials for constructing processing equipment to avoid pro-oxidant metal contamination (30, 31, 32, 33). A generation ago, the maximum allowable amount of soybean oil in margarine was 30% (34). Improved oil stability, flavor, and odor, resulting from PHT research has removed this limit and now margarines may be made from 100% soybean oil. Net value added by improvement in flavor stability is estimated to be 2 cents per pound (35, 36).

Protection of the food and feed supply against mycotoxins--the case of aflatoxin. Following the identification of the mold toxin, aflatoxin, as the cause of deaths in England of thousands of poultry fed a moldy peanut meal, USDA scientists initiated an investigation of peanut stocks stored in this country for the presence of aflatoxin (36a). As a result of positive findings, all farmers' peanuts are now screened at the point of first purchase for the presence of the aflatoxin mold using a rapid method developed by USDA scientists (37). Questionable lots are analyzed for aflatoxin following sampling protocols also developed by USDA researchers (38). Final consumer products produced by industry are monitored by the manufacturer and FDA to assure that FDA tolerances are met. USDA scientists surveyed other stored commodities--corn, wheat, grain sorghum, barley, soybeans, and cottonseed--for possible aflatoxin contamination (39, 40, 41). Significant incidence of aflatoxin was found in corn and cottonseed, especially in corn grown in the southeastern states, and cotton grown under irrigation in the southwestern states. Although the mold producing aflatoxin had been considered to attack commodities only under storage conditions of high humidity, USDA scientists determined that field infection was an important site of contamination of both corn and cottonseed (42, 43). This was an important discovery with respect to devising control methods which are now under investigation. Meanwhile, rapid methods for detection and measurement of aflatoxin in corn and cottonseed have been developed for use by industry in monitoring purchases of these commodities (44, 45, 46) and processes for inactivating aflatoxin in contaminated corn and cottonseed meal for feed use have been developed that are now in final stages of testing to establish the safety of the treated product (47, 48).

Durable press finishes for cotton fabrics. Durable-press (once called wash-wear) finishes became essential for cotton to hold its place in the market. USDA research has had a major role in the development of the general technology on which today's multibillion dollar industry is based and the world's scientific literature on the subject contains numerous developments that stems from USDA research (49). The "why" of smooth drying fabrics was elucidated. Progressively improved finishing agents including ureas, propylene ureas, and the carbamates were developed by USDA and adopted by industry (50, 51, 52, 53). The first durable-press finishes were subject to removal by severe laundering conditions and damage by chlorine bleaches. These problems were solved by the carbamate finishes (53, 54, 55). Additive finishes were developed to make soil removal easier, to improve the hand and appearance of the fabric, and to improve fabric resistance to abrasive wear (56, 57, 58). The laboratory played a major role in the development of polyethylene softeners, and in the development of mixed catalyst systems including both organic acid and aluminum chlorhydroxide types (51, 59). Yarn and fabric structures best suited to durable-press finishing were determined. One-third of all cotton marketed domestically in 1979, farm value over $670 million, was in the form of durable-press fabrics (60). Value of durable-press finishes to the consumer based on savings of time and energy in the ironing of men's shirts alone has been estimated to be $1.2 billion annually (60a). Two USDA scientists received awards for their contributions to the development of durable-press finishes for cotton fabrics. W.A. Reeves received the Olney Medal, the highest award of the American Association of Textile Chemists and Colorists in 1966 (61), and J.D. Reid was recipient of the 1972 John Scott Award, a medal, citation, and $4,000, which is presented to ingenious men who make useful inventions benefiting mankind (62).

Changing practices for cotton ginning. For many years it has been recognized that the operation of cotton gins for about 90 days or less each year is a very inefficient use of ginning facilities. This is especially true for the new high-capacity gins which in some cases represent an investment of $1,000,000 or more per gin. In order to operate cotton gins at a higher percentage of capacity, seedcotton must be accumulated during the harvest season and held for ginning at a later date. To facilitate this, a method of pricing multiple bale-lots of seedcotton was developed by SAES researchers. The ability to determine the market value of cotton before it is ginned permits producers to continue to sell this cotton at harvest for cash to pay production loans, etc. It facilities the accumulation of cotton by ginners for ginning during the off-harvest season. According to USDA researchers, the potential savings in ginning cost from this method of operation amount to $5.00 or more per bale or $60,000,000 or more per year to domestic cotton growers (63). (See Appendix for additional examples.)

Examples of PHT Research That Have Not Yet Been Commercialized

Not all PHT research having potential commercial applications has been adopted by industry and several reasons for this may be cited. A reason frequently given is the need by industry for patent protection for at least a limited period in order to reasonably assure the recovery of developmental costs. In this regard, legislation was passed by Congress in 1980 (64) that permits the issuance of limited exclusive licenses (e.g., for 5 years) to practice inventions covered by government-held patents. Of the examples of research not yet commercialized cited below, their nature is such that commercialization of some may reasonably be expected in the near future. Adoption of others, however, may depend on further increases in the cost of energy or petrochemical raw materials, amortization of equipment used in present processing methods, or the market potential for the product as, for example, in case of the process for separating a food grade protein from alfalfa.

There follow more than a dozen examples of research accomplishments in PHT that have not yet been commercialized:

> ...a process for the fractionation of tallow to yield higher-valued fractions. One fraction has properties similar to high-cost imported cocobutter, a second is quality cooking oil, and a third fraction has characteristics that are promising for use in processed foods (65, 66).
>
> ...a process for producing an edible, high-protein flour from glanded cottonseed. The process utilizes conventional oilseed processing operations and air-classification techniques and should have good technical feasibility for commercial application (67):
>
> ...a borax-based finish that imparts a high degree of smolder-resistance to cotton upholstery fabrics, and hence improves their safety. Minimal wetting for application, and hence saving on the energy required for subsequently drying the fabric, contributes to the economy of the finish (68).
>
> ...a vapor phase, steam-ozone treatment for shrink-proofing wool either in the form of top, yarn, or fabric. The treatment also improves the spinning properties of cotton and mohair (69, 70).
>
> ...a solvent dyeing system that dyes wool extremely rapidly--seconds versus hours as at present. It promises substantial energy savings for dyeing woolen fabrics (71, 72).

...a process for recovering a food-grade protein fraction from alfalfa having nutritional value comparable to casein and also good functional properties. The process is a modification of the process currently being commercialized for the production of a protein-xanthophyll feed product that will be sold to the poultry industry (73, 74).

...a process for preservation of fresh hides with bisulfite that eliminates the salt pollution problem and greatly reduces water usage associated with traditional brine preservation. It yields a quality raw material for making good leather (75, 76).

...development of starch derivatives for use as encapsulating agents for herbicide formulations. The sustained release of herbicides afforded thereby can improve the efficacy of weed control, reduce the impact of chemicals on nontarget organisms and the environment, and provide greater safety to farm workers (77).

...starch-based chemicals for use in rubber that insure quality products while greatly reducing the energy required for manufacture (78).

...biodegradable starch-based plastic film mulches for vegetable crops that preserve soil moisture, retard weed growth, and eliminate removal and disposal costs of petrochemical-based plastic films now used (79, 80).

...several wild and uncultivated plants as potential sources of raw materials for the plastics, lubricants, rubber, specialty chemical, and paper products industries. A survey of uncultivated species and cooperative research with agronomists and plant breeders has elevated several of these to potential farm crop status. Examples are crambe, an oilseed containing an unusual fatty acid, and kenaf, a replacement for forest trees in making pulp for either newsprint or quality printing papers (81, 82, 83, 84).

...a method of doubling the storage life of peaches and nectarines. It involves interrupting storage at low temperature periodically, before chilling injury takes place (85, 86).

...an experimental van container with under-the-floor air distribution for maintaining uniform temperatures in refrigerated shipments of perishables. This type of construction is ready for application by manufacturers of refrigerated containers, trucks, and trailers (87).

As a concluding word it can be emphasized, as noted earlier, that a number of factors influence the commercial adoption of USDA or SAES research findings having potential industrial applications. Not all are commercialized, but neither are all those developed through research carried out by private firms. Some may be commercialized almost immediately after the findings are available, while others may require changes to adapt them to industrial practice or procedures, or may require further process, product and/or market development. Although an analysis has not been made of the time elapsing between the publication of applied PET research and its adoption by industry, it is estimated that most commercialization has occurred within ten years after publication of the research. In some cases, however, a much longer period has elapsed. For example, USDA research on the production of grain alcohol in the 1940's and its use in blends with gasoline as a fuel in automobiles and tractors (88, 89, 90), was not fully utilized (because of relative prices of alcohol and gasoline at the time) until about two years ago when it provided background information for the current production and use of gasohol. Similarly, USDA research on the development of guayule as a source of natural rubber during World War II, including processing methods for its recovery, resin extraction, and demonstration of its quality for tire construction (91, 92) was not commercialized at that time, but only recently has been utilized in the development of guayule as a commercial source of rubber.

Examples where availability of alternate raw materials do not explain the time lapse are provided by soy protein foods. USDA research on processes for the production of soy protein isolates was described in the literature in the late 1930's and early 1940's (93, 94, 95). However, commercially produced products did not become available until 1957 (96). A comparable period elapsed before a new chemical derivative of soybean fatty acids developed by USDA research was produced commercially. Published in 1957 (97, 98), the new chemical was not utilized commercially until 18 years later; during this time, industry had conducted much research on applications which they covered by U.S. patents (99). Another example is the adoption by industry of a USDA process for the production of dried fruit juice powders (100). Described in publications in the 1950's, the product became commercially available about 20 years later (101). In this case, military procurement was the incentive to develop production facilities.

Section Two

INVESTMENT IN PHT RESEARCH AND FUNDING TRENDS IN THE NATIONAL, STATE, AND PRIVATE SECTORS

> Detailed data and an analysis of investment in food and agricultural research in the United States is presented in Paper #2, Work Group II, prepared by Joseph Havlicek, Jr., and Daniel Otto. Much of this section is extracted from the Havlicek and Otto paper (102).

Performers of PHT Research

Performers of PHT research include Federal, State, and private institutions; state institutions include both the 1862 Land-Grant colleges and those authorized in 1890; private institutions include manufacturing firms, research foundations, and nonagricultural colleges and universities.

In the USDA, several agencies conduct PHT research: Agricultural Research Service (ARS), Economic Research Service (ERS), Cooperative State Research Service (CSRS), and Agricultural Marketing Service (AMS). Over the years, these agencies have had various designations and programs now included in them have previously been variously combined or deployed. It should also be noted that AMS is primarily a regulatory agency but does engage in and support some marketing research; ERS is also engaged in monitoring services; CSRS administers Federal formula funds to SAES; and several of the agencies indicated above have authority to support contracts and/or grants research at non-Federal institutions.

Sources of Funds for PHT Research

Sources of funds for PHT research include the Federal Government, individual state governments, industrial firms, trade associations, and private foundations. While the data available for private industry's expenditures for PHT research can only be regarded as approximate, reasonably accurate data are available for the part that is publicly funded--that of the SAES and the several agencies of USDA. However, the following must be recognized in considering the public funding data in this section of the report.

Post harvest technology embraces the following goals of the USDA/SAES national agricultural research program: 1) expand the demand for farm products by developing new and improved products and processes and enhancing product quality, 2) improve efficiency in the marketing system, 3) expand export markets and assist developing nations, and 4) protect consumer health by assuring food safety and wholesomeness. In estimating the funds devoted to PHT, funds devoted to specific research problem areas (RPA) within a national goal were considered to be PHT expenditures if any part of the RPA was related to post harvest technology and/or marketing. This has resulted in some upward bias in the PHT expenditures indicated in this report.

In addition, it is difficult to clearly segregate research expenditures from other activities in agencies like ERS and AMS which have multiple functions as is indicated above. It must be recognized, too, that the only period (1966-1979) over which data are available is a relatively short time span on which to base trends and that the most recent available data are those of three years ago.

Escalating inflation obscures trends in funding since dollar expenditures cannot be compared over time due to declining buying power of the dollar. To make meaningful comparisons of funding between one year and another, an appropriate deflator is needed and one, to be defined later, has been selected so that trends can be discussed in the fiscal data that follow:

Total Public PHT Research Expenditures and Trends

Total PHT research expenditures in 1966 were $87.2 million, consisting of $71.8 million Federal funds (Table 1) plus $14.0 million State funds (Table 2) plus $1.4 million private funds provided to SAES (Table 2). The total became $212.1 million in 1979 representing a substantial current dollar increase. However, there was a decrease of 1.5% when adjusted to real dollars.

During this same time span, value added in the ag-food marketing sector increased from $57.2 billion in 1966 to $164.5 billion in 1979. After adjustment of the 1966 and 1979 figures for devaluation of the dollar, real dollar expansion of the ag-food marketing sector during this period was from $60.0 billion to $69.9. In contrast to this increase of 16.5%, total research funding for PHT decreased 1.5% in real dollars.

The two paragraphs above make obvious the need for a deflator to facilitate comparison of year-to-year funding. Consequently, further reference to PHT research expenditures in this section of the report is in terms of real dollars, that is, current dollars adjusted for declining buying power. Since 1967, was selected as the base period, real and current dollars are the same in 1967.

Table 1. Allocation of Federal Funds for PHT Research by Performer, 1966 and 1979[a]

$1000

Performer	1966			1979		
	Current $	Constant[b] $	%	Current $	Constant[b] $	%
Economic Research Service	8,095	8,494	11.3	22,292	9,516	14.9
Cooperative State Research Service[c]	-	-	-	3,544	1,506	2.4
Agricultural Research Service	46,211	48,491	64.3	86,336	36,692	57.2
Total Federal Perfomers	54,306	56,985	75.6	112,272	47,714	74.5
State Agricultural Experiment Stations						
Formula Funds	10,877	11,413	15.2	22,809	9,694	15.1
Regional Research[d]	(3,062)	(3,213)	(4.3)	(5,841)	(2,482)	(3.9)
Cooperative Grants and Agreements	1,559	1,636	2.2	3,007	1,280	2.0
Other	5,050	5,299	7.0	12,667	5,383	8.4
Total SAES	17,485	18,348	24.4	38,483	16,357	25.2
Industry R&D	3,000	3,200		-	-	-
Total Federal Funds	71,792[e]	75,333[e]	100.0	150,755	64,071	100.0

[a] Source: Havlicek and OTTO, OTA Paper No. 2 (102).

[b] Adjusted to 1967 dollars.

[c] Funds used to administer Federal research funds given to the states and obligations of CSRS administered special grants. Funds were not reported separately in 1966.

[d] Included in Formula funds.

[e] Federal funds allocated to Industry R&D not included in total because data for 1979 were not available.

Table 2. Source of SAES Funds for PHT Research, 1966 and 1979[a]

$1000

Source of Funds	1966			1979		
	Current $	Constant[b] $	%	Current $	Constant[b] $	%
State	14,022	14,714	42.6	56,005	23,802	56.1
Private	1,373	1,441	4.2	5,333	2,266	5.3
Federal	17,485	18,348	53.2	38,483	16,357	38.6
USDA	12,436	13,049	37.8	25,816	10,974	25.9
Formula	10,877	11,413	33.1	22,809	9,694	22.8
Regional[c]	(3,062)	(3,213)	(9.3)	(5,841)	(2,482)	(5.9)
Contracts, Grants, Agreements	1,559	1,636	4.7	3,007	1,280	3.0
Other Federal	5,050	5,291	15.4	12,667	5,383	12.7
Total	32,880	34,503	100.0	99,821	42,425	100.0

[a] Source: Havlicek and Otto, OTA Paper No. 2 (102).
[b] Adjusted to 1967 dollars.
[c] Included in Formula funds.

PHT Research Expenditures by Performer and Trends

Expenditures by the Federal, State, or private performers of PHT research in 1966 and 1979 are given in Tables 1 and 2. In the USDA, in-house expenditures declined from $57.0 million in 1966 to $47.7 million in 1979, a decrease of 16%. In ARS, expenditures for PHT research declined 25%. In the SAES, funding increased from $34.5 million in 1966 to $42.4 million in 1979, an increase of 23%. Thus, while USDA is still the dominant performer of PHT research, it dominancy waned between 1966 and 1979; PHT research funding in SAES was at only 61% of the level in USDA in 1966, but had increased, relatively, to 89% by 1979.

According to Havlicek and Otto in OTA Paper No. 2, PHT research and development in private industry increased from $138 million in 1966 to $185 million in 1975, the last year for which data are available. These figures reveal that PHT research and development in the private sector was about twice that in the public sector (SAES plus USDA) in 1975. However, such a comparison may be deceptive. The PHT research done by industry is primarily for the improvement or modification of its own products or processes to maintain or increase its profits. Much of private research may not be comparable with that performed by USDA and SAES in the public interest. There is evidence that this is so. In the 1979 PHT Assessment Report of USDA's Science and Education Administration, a consulting firm (IRI/RC) found, in interviews with officials of 70 firms and associations, that they did little of the "kind" of PHT research done in USDA/SAES.

PHT Research in SAES by Source of Funds and Trends

While USDA research in PHT is supported almost exclusively by Federal funds, that in SAES enjoys multiple support, receiving funds from Federal, State, and private sources (Table 2). This table indicates that Federal funds to support SAES research in PHT are of three kinds administered by USDA: 1) formula funds, 2) regional research, and 3) grants, cooperative agreements, and contracts. The SAES also receive some funds from Federal agencies other than USDA. Table 2 also indicates that total Federal funding to support PHT research in the SAES decreased from $18.3 million in 1966 to $16.4 million in 1979, a decrease of 10%. Meanwhile, State appropriations for PHT research in the SAES increased from $14.7 in 1966 to $23.8 million in 1979, an increase of 62%. Funds from private sources to support PHT research in SAES increased 57% over this period to $2.3 million in 1979.

These trends indicate that while Federal support of PHT research in the SAES has decreased relative to State and private sources, Federal funds are still an important source of support for PHT research in the SAES.

Another significant trend is apparent when total funds available from all sources for (USDA/SAES) PHT research in 1966 and 1979 are compared with the total available for ag-food research in those two years. Research in PHT accounted for about 24% of the total in 1966 but declined to about 19% in 1979. Federal funds for PHT research as a percentage of Federal funds for all ag-food research declined from 32% in 1966 to 26% in 1979. These changes imply that administrators have placed a lower priority on PHT than other kinds of ag-food research during this period despite the obviously increasing relative importance of what happens in the post harvest sector of the ag-food industry.

Allocation of Federal Funds for PHT Research

Federal funds support PHT research in several Federal agencies, primarily agencies of USDA, and support PHT research in the SAES. A small amount of Federal funds may also be used to support PHT research in non-Land Grant universities, and private research institutions.

It should be pointed out that accounting for allocation of Federal funds is complicated somewhat by the structure of the budget. The Federal funds for in-house ARS research are incorporated in the ARS budget and most of the Federal funds for SAES research are incorporated in the CSRS budget. However, research in other agencies of USDA such as ERS and AMS, is funded directly or in various combinations in the budgets of those agencies and it is sometimes difficult to segregate research funds from those devoted to other activities.

Allocation of Federal funds for PHT by performer is indicated in Table 1. The Agricultural Research Service and Cooperative Research Service are dominant among the Federal agencies in performing or supporting PHT research. The other major Federal performer is the Economic Research Service. The Agricultural Research Service accounted for 85% of the funds used by Federal performers in 1966 and 77% in 1979; ERS accounted for 15% of the Federal PHT research in 1966 and 20% in 1979. Federal performers accounted for 76% of the Federal funds for PHT research in 1966 and 74% in 1979. The remaining 24% of the Federal funds in 1966 and 26% in 1979 appropriated for PHT research were allocated to State Agricultural Experiment Stations. The largest share of the total allocated to the SAES was through formula funding.

Total Federal funding for PHT research decreased from $75.3 million in 1966 to $64.1 million in 1979. Within these totals, funds allocated to Federal performers decreased from $57.0 million in 1966 to $47.7 in 1979, while Federal funds allocated to the SAES for PHT research decreased from $18.3 million to $16.3 million in the same period. Agricultural Research Service has been the main loser in Federal support of PHT research, its funds decreasing 16% in constant dollars during the fourteen-year period. In contrast, ERS has shown a modest gain in funding for PHT research.

Allocation of State Funds for PHT Research

State appropriations for PHT research increased from $14.6 million in 1967 to $23.0 million in 1977 (Table 2). As far as can be determined from available records, all state appropriations for PHT research are utilized by the SAES. State funds accounted for 43% of the SAES expenditures on PHT research in 1967 and 50% in 1977. State funding of PHT research at the SAES increased by $8.4 million between 1967 and 1977, an increase of 58%.

Allocation of Private Funds for PHT Research

Private funds for PHT research are allocated primarily to the company's research department or by the company to other private performers (such as universities or research institutes), or to public performers (such as SAES).

Private funds for PHT research, believed to have been about $134 million in 1967, increased to about $168 million by 1975 and were probably further increased by 1979.

Commodity and trade associations provide an unknown, but probably a relatively small, amount of support for PHT research through check-offs and other funding mechanisms. However, most of this research is designed to enhance or maintain the position of a particular commodity in the market. Some of this activity may be product promotion in the guise of research and some is designed to evaluate various promotion schemes.

Section Three

BENEFICIARIES OF PHT RESEARCH

Benefits and the Economic System

An economic system utilizes the available natural resources, the services of its people (labor), and capitalistic processes to provide goods and services and otherwise enhance the well-being of the populace which it serves. Research is designed to enhance the efficiency of the economic system. Increased efficiency is manifested primarily in increasing output per unit of labor input.

It is the role of government to protect the system from domestic and alien predators (cartels and other monopolistic practices), maintain social tranquility, provide protection against enemies and external duress, provide education to enhance the skills and productivity of the labor force, foster economic development through advancing science and technology, maintain a pleasant and clean environment, establish and maintain a sound monetary system to foster specialization, provide investment funds at low and stable interest rates, and foster exchange in both domestic and international markets.

Provided a government fulfills its role satisfactorily, virtually all of the benefits of research it supports accrue to its consumers. In the United States all of the benefits accrue to Americans except for the benefits foreigners obtain from exported American products. Consumption--the enjoyment of goods, services, and aesthetic pleasures--is the motivating force of the economic system. Persons engage in production activities in order to acquire exchange to purchase goods and services for consumption. Benefits of research accrue to producers to the extent that individuals gain an advantage in acquiring consumer goods and services. Advances in productivity--primarily labor efficiency--in a competitive economic environment is passed on to consumers in the form of lower prices. Benefits of research accrue only to those producers who are early adopters of the new technologies created by research, and/or have the power to circumvent competition.

Thus, it is a responsibility of government, primarily the Federal Government, to foster economic development through education, research, and technical innovation, and to provide a competitive economic environment to insure that the benefits of such activities are equitably distributed. Innovators and early adopters gain short-lived advantages even under a highly competitive economic system. But a competitive system also places pressures on the laggards to catch-up or pursue other alternatives.

Research and technical innovation in post harvest technology contribute to consumer well-being by: 1) increasing the supply (reduction in losses) of foods and kindred products reaching consumers and thus reducing prices to consumers, 2) increasing the value of foods and kindred products by preservation and distribution throughout the year thus reducing prices to consumers for out-of-season products, 3) increasing the value of foods and kindred products to consumers by distributing them over space as desired thus reducing prices to consumers far removed from the areas of production, 4) increasing the safety of foods through preservation, and 5) improving the nutriture and the health of the population by providing a large variety of high quality foods. Research developments in post harvest technology in the latter areas contribute to personal exuberance, social tranquility, and reduced medical costs.

As a result of many successful commercial developments stemming from research, a wide variety of high quality foods and kindred products are readily available to nearly all of the people of the United States virtually all of the time at the lowest relative prices of any time or place in history. This unprecedented achievement was accomplished with a relatively modest public investment in research and education, and with private industries willing to risk capital to adopt them and reduce them to practice. Continuing benefits of such a modest investment of public funds is rather obvious and rather substantial. It can never be known what our current situation would have been with a lesser or a greater investment of public funds. However, our current, excellent food preservation-distribution system, as impressive and efficient as it is, should not be taken for granted. Increasing scarcity and escalating prices of liquid fuels on which our food preservation-distribution system is so heavily dependent, have already jeopardized the efficiency of the system. Appropriately directed and adequately supported research can provide alternate technologies and/or alternate energy sources. At best, real costs of preserving and distributing foods can only increase in the immediate short run. But costs are more likely to increase more rapidly and persist for a longer period unless the major problems are given research attention.

The Economic Framework of Benefits of PHT Research

The concept of economic surplus provides the theoretical framework for assessing the benefits of PHT and other research. This framework is depicted in Figure 1. Price (P) is on the vertical axis and supply (Q) is on the horizontal axis. The consumer demand for a product or service is represented by D. This simply says that the quantity demanded increases as the price decreases. Supply, represented by S, is an aggregation of marginal cost curves. This says that marginal costs increase with output (Q) and subsequently increasing prices are necessary to increase supply. Ep_1 represents the equilibrium price and Eq_1 represents the equilibrium quantity.

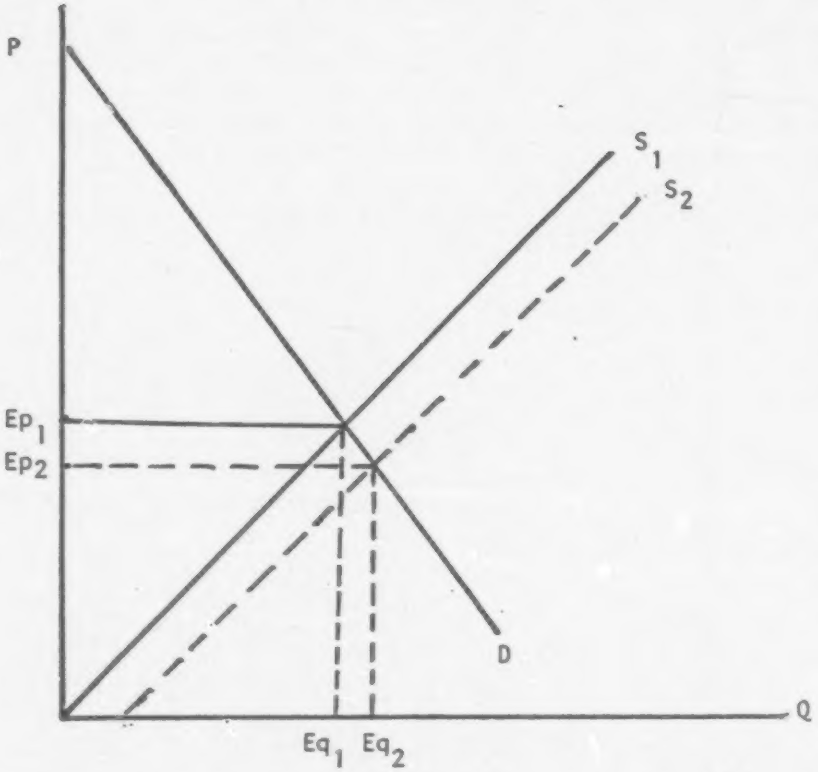

Figure 1. The Economic Framework of Benefits of Research and Technical Innovation

The economic surplus is represented by the triangle to the left of the intersection of the D and S lines. That part above the price line is consumer surplus and that part below the price line is producer surplus. A progressive economic system will increase economic surplus over time by shifting the demand curve upward and to the right and/or by shifting the supply curve downward and to the right. An upward shift in the demand curve results from increasing real income.

A downward shift in the supply curve results from decreasing costs. Research and technical innovation come into play by reducing marginal costs and subsequently shifting the supply curve downward and to the right as depicted by S_2. The end result is a reduction in the equilibrium price to Ep_2 and an increase in output to Eq_2. It is thus obvious that consumers benefit from both a lower price and a large quantity. However, the division of the increased economic surplus between producers and consumers depends on the nature of the supply and demand functions.

The economic framework and the concept of economic surplus apply to marketing services and for products at the wholesale and retail levels as well as to primary products at the farm level. There are, for example, technologies and costs associated with preservation and storage (distribution over time). There is also a demand for storage. The same applies to transportation and other transfer costs (distribution over space). Moreover, demand at the farm level is derived from consumer demand through retailers, wholesalers, processors, and handlers. The important consideration is that the same framework and concepts apply to all economic activities--the production of goods and services and their distribution through time and space.

Primary Producer (Farmer) Benefits from PHT Research

Primary producers are defined as those who engage in planting, nurturing, protecting, and harvesting crops, and/or breeding, husbanding, nurturing, and protecting food animals or food producing animals. This distinction is made because, from an economic perspective, handlers, assemblers, processors, transporters, storage operators, brokers, wholesalers, and retailers are also producers. For example, flour and other products are produced from wheat and subsequently, bread is produced from flour. Either the primary, intermediate, or final products may also be stored and transported, and may change ownership several times.

Farmer benefits from PHT research are rather obvious. The marketing system enhances the value of farm commodities by changing their form and distributing the products over time and space. The demand for farm products is created by the demand for intermediate and consumer products. For example, few households buy wheat but most buy bread and some buy flour. Thus, the demand for flour stems from the demand for bread and the demand for wheat is due to the demand for flour. Primary producers benefit from PHT research when marketing services are made more efficient. Increased efficiency in the marketing system shifts the derived demand at the farm level nearer the retail level. The initial adjustment at the farm level will be an increase in price, but when a new equilibrium is established both price and quantity will be increased at the farm level.

Processor and Retailer Benefits from PHT Research

Processors and retailers benefit from PHT research when more efficient technologies reduce their operating costs. Eventually most of these cost savings will either be passed forward to consumers in the form of lower prices or backward to primary producers in the form of higher prices for raw products. Retention of cost savings in the processing and retailing sectors depend on the degree of competition in these subsectors. The greater the degree of competition, the less likely it is that the cost savings will be retained as profits.

It is true, of course, that early adopters of more efficient technologies can, by reducing prices, gain a larger share of the market until competitors adopt the more efficient technologies and can also operate at the lower price level. An example of more efficient technology paying off to an early innovator is the adoption by a large chain store of a change in refrigeration practices for the fall crop of California tomatoes. Research of the USDA/SAES had shown that tomatoes should not be transported at temperatures less than 55°F, yet the accepted commercial practice was to refrigerate railroad cars to maintain temperatures at or below 45°. This practice cost about $95 to $100 per refrigerator car, entailed a long (10-day) ripening period at the market, and caused some chilling injury, manifested by decay, off color and off flavor. The chain store changed its refrigeration practices on recommendations of researchers, and used little or no refrigeration. The result was shorter ripening period at the market, lower refrigeration costs, and a better product. The savings in cost enabled the chain store to sell tomatoes at 10 to 15 cents less per pound than previously; thus, passing on to the consumer some of the savings and, as a consequence, getting a larger share of the market.

Labor Benefits from PHT Research

Research that springs more efficient technologies usually makes possible increased labor efficiency, and provides opportunity for increasing wages and salaries without placing an upward pressure on retail prices. Adoption of more efficient technologies also provides the opportunity for labor to move to other sectors producing higher order goods and/or services. The end result is a wider variety and more abundant supply of all goods and services. Labor also benefits indirectly in their role as consumers.

Research that provides for more efficient use of energy and capital provides more residual revenue for increased wages and salaries in real terms. Conversely, rising prices of energy and investment funds (manifested in increasing interest rates) place downward pressure on salaries and wages, upward pressures on retail prices, and downward pressures on farm prices. Unfortunately, these are the conditions that dominated during most of the past decade. Such pressures as rising energy prices and rising interest rates can be offset by improved efficiencies stemming from PHT. In fact, if it were not for the efficiencies made possible by past PHT research, retail prices would have risen even more rapidly than they have. Increases in wages and salaries, without compensating increases in labor efficiency, only augments labor's problems. Workers and their dependents stand to gain the greatest share of the benefits of PHT research. This segment of the population also receives the major share of the benefit accruing from increased efficiency of farm production. Real wages and salaries are augmented either directly or indirectly by more efficient technologies in any sector, and this is particularly true of the realm of food marketing. Since food purchases have first claim on wages and salaries, it is only when food can be acquired with a shrinking proportion of wages and salaries, that the level of affluence can rise. Subsequently, a rising level of affluence contributes to social tranquility. The direction the level of affluence of the populace is moving, rather than its absolute level, is the important factor.

Public (Consumer) Benefits from PHT Research

When research provides the knowledge that makes improved technologies possible, the adoption of the new technologies by industry reduces the cost of their products. In a competitive economic environment, reduced costs force price reductions at the retail (consumer) level. Thus, the consumer is the ultimate and major beneficiary of PHT research. The development of frozen concentrated orange juice and improved methods of harvesting, storage, and scald prevention in apples are examples.

Benefits from PHT Research as Related to Funding Sources

Inasmuch as consumers are the major beneficiaries of PHT research, and food and kindred products flow freely in interstate commerce, equity with respect to benefits is best when PHT research is Federally funded since then it is paid for by all of the people. The only seepage under Federal funding with respect to who benefits and who pays is the benefit that sometimes flows to foreign consumers through exports. It should be noted in this regard that there is also very often a flow of benefits in the opposite direction. Controlled atmosphere storage of fruit started in England but now the greatest use of this technology is in the United States even though the application is worldwide. The physical properties and many of the practical applications of refrigerants, such as ammonia, were worked out in Germany, France, and England before this knowledge was applied here. We owe much to the pioneering of the Frenchman, Pasteur, in the field of microbiology which laid the groundwork for the sanitation practices that now characterize our food industry. The results of Federally funded research are usually more widely disseminated than those of other public or private research. Wide dissemination increases opportunity for adoption and wide adoption promotes competition. A high degree of competition insures that consumers are the ultimate and major beneficiaries of PHT research.

Under state funding, benefits of PHT research flow to consumers in that state but also to consumers in other states. Consumers (taxpayers) of the funding state pay for the benefits realized by all Americans. Even benefits accruing to producers, processors, and retailers, who adopt the new technology they have paid for, are diluted because of spillovers outside the state.

Private firms will support only that kind of PHT research that has the potential to enhance their profit position. Results of such research are privileged and are not freely shared with others. The incentives for private firms to support PHT research are greatest under market structures that depart from the purely competitive--market structures such as monopolistic competition embracing product branding, oligopolies-oligopsonies, cartels, and monopolies-monopsonies. Under market structures approaching pure competition there is less incentive to support research since individual firms have no control over price or market supply and there is accordingly little opportunity to significantly enhance profits.

It should be noted that capacity to conduct or support PHT research in the private sector is confined to the larger firms. Small processors, fabricators, transporters, and merchandizers cannot afford to do or support research. Their survival in a competitive world depends on the "free-to-the-public" results of publicly supported research.

Temporary Disadvantages Created by PHT Research

There are instances when certain segments of the economy may be adversely affected in the short run by new technologies created by PHT research. Introduction of dollies, fork lift trucks, and other labor-saving equipment in the ag-food distribution system increased labor productivity, but it also temporarily displaced labor and caused shifts in employment. Moreover, new product development, although beneficial to the consumer and some segments of the economy, may temporarily have adverse effects on others. An example is the development of margarine from vegetable oils. This product, which has replaced butter to a great extent as a table spread, was disadvantageous to the dairy industry. However, jobs lost in butter manufacturing plants became jobs gained in margarine plants, and dairy farmers, at least in the Mid-West, now have the soybean as a cash crop to provide the oil for margarine. Future development and wide consumer acceptance of "synthetic" milks made from vegetable proteins and fats may also have temporary adverse effects on the dairy farmer, as would the development of meat analogs based on vegetable proteins on the meat industry. However, the magnitude of such effects will depend to a considerable extent on the demand-supply relationships for milk and meat when competitive products become available in a variety of consumer-acceptable forms.

Water and air pollution problems have sometimes accompanied the large-scale processing of agricultural products and adoption of new research-based technologies. These problems have not, of course, been peculiar to the ag-food industry but have been common to the industrial sector of the economy and work disadvantage on those exposed to them. Recent public concern about environmental pollution, however, has led to research in both the private and public sectors that has already contributed greatly and should continue to be pursued to ameliorate pollution problems in the ag-food system. In view of current governmental regulations, it is expected that new technologies will make it possible to avoid or circumvent such problems as new processing plants "come on stream."

It may be concluded that although short-term disadvantages in certain sectors of the economy may arise from the application of PHT research, they are far outweighed by the benefits that accrue to most everyone in the long-term.

References 103 through 112 provide support for, and additional reading relevant to, the information contained in this section.

Section Four

THE ROLE OF THE PUBLIC AND PRIVATE PARTICIPANTS IN PHT RESEARCH IN RETROSPECT AND PROSPECT

The role of the Federal Government, State Agricultural Experiment Stations, and the private sector in agricultural research generally, is presented as Paper #4 prepared by Drs. A.H. Moseman, J.J. Robbins, and Harold Wilcke.

How We Got Where We Are

Well before the invention of the term post harvest technology to include everything involved in getting agricultural products from the farm to the consumer, the USDA, SAES, and private industry looked primarily at whole commodities and researched those aspects of production, harvest, storage, processing, and marketing that seemed most likely to achieve their goals at the time. The SAES as well as USDA were organized along commodity lines and research ran the gamut from research on seed, soil, and egg to research on the final food, fiber, and other nonfood products. Wisconsin, for example, researched not only dairy cattle genetics, husbandry, and feed efficiency, but did historic studies on milk processing. At about the same time, the Bureau of Animal Industry of USDA, while emphasizing research to improve means of detection and treatment of animal diseases, noted in its "Century Souvenir Book" in 1900, "...one of the most important sections of animal industry is that devoted to dairying--the production of milk, butter, and cheese." The report spoke of a new division of dairying, which was, of course, the forerunner of the Bureau of Dairy Industry. Private industry, then as now, did research on any aspect of agricultural production, processing, and marketing that they felt was necessary to remove obstacles to obtaining a continuous supply of the commodity needed for their product(s), and to lower the cost of their raw material, or to improve its quality. Some industries also researched means to improve quality and lower cost of their established food and fiber products, to devise new products, and to improve their markets for all of them.

Some time after the turn of the century, organization of agricultural research along disciplinary lines became popular, resulting in the SAES in such divisions as plant physiology, plant pathology, animal pathology, and in USDA in such Bureaus as Chemistry, Entomology, and Agricultural Engineering. This fragmented what we now call PHT research, making it necessary to look in more than one place at each SAES and in USDA to find out what PHT research was being done on corn, for example, and making it necessary to develop some means for coordination of these dispersed activities within the SAES on the one hand and in the USDA on the other. The SAES and USDA, for the most part, continued to do in the new organizational entities about the same kind of production and PHT research they had been doing prior to that time. No one seemed concerned about the programs or roles of each, except to the extent that those in USDA who were responsible (Office of Experiment Stations) for accountability with respect to Federal formula funds to SAES were familiar with SAES programs and could communicate this information to those responsible for intramural research in USDA. Industry found it more difficult to keep abreast of public research activities in the new organizations but continued to fill voids by doing research themselves if it were vital to their welfare.

This picture was further complicated in the 1930's by a national policy change reflected in the renaming of the Bureau of Chemistry as the Bureau of Agricultural and Industrial Chemistry (BAIC), recognizing that USDA had an interest in and a responsibility for doing research and development on the industrial utilization of agricultural commodities. This change placed emphasis on a new aspect of PHT research--the creation of new food, fiber, and industrial products based on agricultural commodities as renewable raw materials. The move in this direction was fueled by the agricultural surpluses of the time and resulted in the creation by Congress of the four regional research laboratories in Berkeley, California; Peoria; Philadelphia; New Orleans; and in the 1960's a fifth laboratory in Athens, Georgia. These laboratories of BAIC were charged by the Congress to develop markets for agricultural surpluses and, ideally, additional, stable markets for the farmers' commodities in more normal times. Some of the BAIC's research programs, particularly in the food fields, looked as one would expect, very much like some of the activities being performed in the SAES and in other Bureaus of the USDA. Under the leadership of the Chief of the Bureau, Dr. Henry G. Knight, they were pursued with vigor by a relatively young professional staff with active participation by industry and with the enthusiastic support of several key members of the Congress.

The BAIC's "trespassing" on the turf of the SAES and of the other USDA Bureaus caused friction within the USDA and at the USDA/SAES interface. Many of the SAES, who vehemently lobbied against the establishment of the regional laboratories in the first place, found it difficult to cooperate with them. Location of the original four laboratories, remote from established SAES, since they could hardly be on the campuses of all of them, was blamed for some of this. Several of the "old line" Bureaus of USDA regarded BAIC as an interloper to be dealt with at arm's length, if at all. Early successes in some BAIC programs in cooperation with the industry (frozen concentrated orange juice, penicillin, washwear cottons) exacerbated the friction.

To help correct its internal problems in this regard, USDA in the late 1940's created the Agricultural Research Administration, an administrative layer between the Bureaus and the Secretary, designed to ride herd on the Bureaus, define research roles, coordinate programs, and attempt to weight USDA programs, through the budgetary process, in accord with what it determined to be priority needs. This effort was not wholly effective because of strong opposition and foot-dragging by the then powerful Bureau Chiefs, all of whom had strong supporters in certain parts of the Congress and in many states. This experience prompted the change made in the early 1950's when the Bureaus in USDA were abolished and the Agricultural Research Service (ARS) assumed their research and regulatory functions. Even though ARS, under Dr. Byron T. Shaw its first Administrator, was empowered to act as a single integrated agency, many continued to regard it as merely a "holding company" for the former Bureaus. However, the creation of ARS did alleviate eventually some of USDA's internal problems, particularly as one-time Bureau Chiefs faded from the picture and professional staff with old wounds retired to be replaced by new personnel who were ignorant of the alleged injustices of the past.

A small ARS project office (2 or 3 professional personnel) arranged for the development of project statements, organized them for purposes of record and reference, and provided a forum for discussion of differences in the roles of the several parts (now Divisions) of ARS in the research to be pursued. The ARS project office also coordinated the research of ARS with that in the Agricultural Marketing Service (AMS) and the Economic Research Service (ERS) whose research was given new impetus with the passage of the Research and Marketing Act of 1946. Appropriate parts of the research in these two agencies and the research of the old BAIC (called Utilization Research and Development after it became part of ARS) made up the bulk of what we now refer to as PHT. The marketing research work of AMS was later transferred to ARS.

Nevertheless, the creation of ARS failed to alleviate problems at the USDA/SAES interface. In the reorganization of the 1950's the former Office of Experiment Stations, the organization of USDA that administered the Federal formula grants to the various states, was made two Divisions in ARS (one for domestic and the other for the territorial experiment stations). This action made the Administrator of ARS responsible for their administration, including recommending budgets for formula funds and coordinating the Federal programs and those State research programs that were financed by Federal funds. Officials of the SAES at the time were not enamored of this development and maneuvered to have a separate agency in USDA with responsibility for administering formula funds. This occurred in 1962 with the creation of the Cooperative State Research Service, thus adding a new facet to the problems of interagency coordination. At that time, it was suggested that advantage be taken of new computer technologies to coordinate Federal agricultural research with State-supported research at the SAES. The machinery and procedures for doing this are now in operation in the USDA. This machinery bears scrutiny as do the organizational and management trends in USDA as they affect PHT research and the interrelationships of USDA, SAES, and private industry.

Reflections on Organization, Management, USDA/SAES/Industry Relations

Through all of the changes indicated above and others that have occurred since 1972, including the establishment and very recent dissolution of the Science and Education Administration, what we are now referring to as post harvest technology research has been combined with, separated from, and recombined with production and other kinds of research time and again in USDA and in the SAES. Considering that PHT as a research entity, has had a relatively short history, the frequency of organizational changes and consequent confusion have tested the determination of the scientific staff in PHT (as well as in other parts of research) to persist with what they regard as important work, as well as the patience of the industry in waiting for USDA management to settle down. Both the veterans in PHT research and the industries that have most benefitted from PHT research, believe that productivity was greater when the various aspects of PHT research were less dispersed throughout USDA than they are now. Dispersion of PHT research into organization units designated principally by titles involving the points of the compass, make it difficult for industry to find where PHT research is being done and to keep track of its progress. It makes it difficult also for scientists to establish the team attitude so necessary for productive research in multidisciplinary areas like PHT.

It is natural perhaps, for one to tend to prefer and defend the merits of organizational styles he has lived with or had a hand in creating. But even such people recognize that there are a host of ways to organize and manage any institution and that not just one of these ways is the only good one. They also recognize that change is sometimes necessary while at the same time decrying the philosophy of some who apparently believe that change for the sake of change is good because the turmoil it creates is a sign of great activity and progress. Nevertheless, the frequency of change in the last decade, and particularly the present dispersion of PHT research in USDA, have made it difficult to continue to do good research. But, even more important, it places PHT research in a poorer position to address effectively the future problems in this area which, as pointed out earlier in this report, concern a clear majority of the problems facing U.S. agriculture. While another reorganization, like another trip to the proctologist, is not to be looked forward to, giving PHT research the organizational prominence and recognizable leadership it deserves, would be well worth any short-term duress it may cause. If this is not done promptly within the recently re-established ARS, PHT research in its entirety should be moved to AMS where its proximity to the regulatory problems in marketing might make for a more mutually appreciative administrative relationship.

The reorganization of ARS and the decentralization of its direction and management that occurred in the 1970's, was designed ostensibly to improve collaboration and efficiency in the USDA-SAES relationship. However, there were many signs at the time that it was really a move in the direction of evolving a single public agricultural research program in the United States, financed wholly or primarily by the Federal Government and performed wholly or primarily by the SAES and other nonFederal institutions. It would appear that this is materializing. Total in-house research funds (constant dollars) in USDA remained the same between 1972 and 1979, while Hatch Act funds to the SAES increased 18% in the same period. This is a strange policy in light of the need for a strong USDA (see the last subsection of this section). It is also strange that PHT research should be the kind most severely affected. While funds (constant dollars) for all in-house research in USDA remained unchanged between 1972 and 1979, funds for in-house PHT research decreased 17%. Of all research in agriculture, PHT research, more than any other, deals with those aspects that are almost wholly of national concern. PHT concerns itself with what happens post harvest--with what happens in trucks, planes, trains, ships, warehouses, and stores--events which are seldom respectors of statelines. This kind of research needs to be approached, more than any other, from the national viewpoint and be influenced by national direction and guidance.

With respect to the present decentralized organization, it is noteworthy that the regional deputies are under greater daily influence of neighboring SAES directors than they are of the more remote administrators in Washington. Under such circumstances, it is inevitable that state philosophy will more and more dominate the agricultural research picture until the first concern will be provincial rather than national problems of agriculture. Is this what the USDA and Congress want?

There should be no embarrassment in returning to a fully centralized USDA research program, answerable to and directable by the Secretary and responsible, through Congress, to all of the people. Lacking centralized responsibility and fully informed, Washington administrators in recent years has been embarrassing, however. Hearings before appropriations committees have repeatedly reflected the difficulty administrators have had in establishing credibility because of the absence in Washington of those whose job it is to operate, direct, and keep fully informed. Separation of those who plan and those who operate has been largely responsible and should be corrected.

Another reflection on organization and management concerns conflicts. At least one reason given for the creation of the late Science and Education Administration in USDA a few years ago, and the ponderous machinery to run it, was to obtain better coordination within the Federal and between the Federal and State research programs and to eliminate causes of presumed conflicts. Over the years, personnel on all sides have taken vicarious satisfaction in parading their grievances about the system and each other. But this was invariably done with more sound than fury, and seldom with any notion that these "conflicts" were serious problems until somebody decided to elevate them to that status. Of course, there are conflicts within USDA! The fact that production research people and PHT research people, for example, are vying for funds annually in the budgeting process is a way of life in USDA and modest winners and graceful losers are few. Of course there are conflicts between USDA and SAES! When decisions are made concerning how much Federal money should be budgeted for in-house research and how much for formula grants, harmony is less than rampant. Of course there are conflicts among the SAES! When more than one state has the competence and desire to do nonformula grant or contract research under Federal financial support, those "out bid" are less than happy. Of course there are complaints from industry! All industries believe "their" area of interest deserves the most public research attention and does not always get it. Many industries feel that public research agencies should confine themselves to very basic research, and that industry should decide which findings have significance for industrial application.

Finally, of course, there are the traditional attitudes and allegiances that Federal, State, and industrial personnel have toward the organizations of which they are part. Many progressive industries regard public research personnel as part of the bureaucracy with which business believes itself to be saddled. They are not always able to conceal their convictions that scientists in public institutions are inferior to those in their own laboratories and that direction in public institutions is less "with it" than that in the private sector. Many in the Land Grant, other universities, and the SAES, associated as they are with teaching and thus constantly exposed to the vigorous young minds of students, feel superior to scientists in USDA who do not usually have the advantage of being similarly stimulated. Although these attitudes have little basis in fact, they are myths so deeply imbedded in the minds of many that they will disappear slowly, if ever.

In the last analysis, none of these attitudes, conflicts, or presumed conflicts is a serious deterrant to productive research and cooperation within and between the public and private participants in PHT research. There is ample evidence of solid accomplishments in PHT research (see Section One and the Appendix) prior to the reorganizations and managerial changes of the 1970's, and there is no evidence that things had improved prior to the reorganization of 1981. While it is too early to evaluate that change, we believe it is a firm step in the right direction.

People here and abroad frequently marvel at the wisdom that created the USDA-SAES system and at its effectiveness for the better part of a century in meeting those problems of agriculture that are resolvable by research and the industrial application of research results. The most recent exponent of this opinion is Senator Harrison Schmitt who, speaking of the government's role in basic research, wrote in the January 16, 1981, issue of SCIENCE, "...government should develop appropriate research partnerships with industry and academia such as those existing in agriculture and aeronautics."

Reflections on Budgeting and Priority Setting

The methods used by the SAES and the USDA in determining research priorities and in developing a budget for agricultural research are described by Havlicek and Otto in their report, "Historical Analysis of Investment in Food and Agricultural Research in the United States," (102). These methods apply as well to PHT research. Our reflections here are confined to the process itself; the question of optimum budget level is discussed in Section Six.

In the State Experiment Stations, the individual scientist, the Department Heads, and the Station Director all have a voice in setting priorities and determining total investment. The State Legislature also has a hand in the process in some states and industry representatives may also influence the nature of research budgets and priorities. Those projects given highest priority by the Station Director have the greatest chance of survival.

The funds allocated to the State by USDA for cooperative research under various Acts of Congress, are subjected to a different kind of review. The Legislative Subcommittee of the Experiment Station Committee on Policy (ESCOP) prepares plans and begins the process of establishing priorities for future research based on the needs as perceived by the Directors of State Experiment Stations. The fate of PHT research proposals in the process will depend on the appeal of the projects to the Director and to the Subcommittee of ESCOP.

Priority setting and budgeting in the USDA take place at three levels: 1) the decision units (DU), 2) agency heads, and 3) the Secretary and his Budget Office. The staff teams organized around the DU's are the key components of the priority setting and budgeting process. Members of these teams are staff personnel and represent research scientists of their respective agencies or unit. It is here that the scientist has the opportunity to participate in priority setting and budgeting guided somewhat by a set of socio-economic goals developed within USDA as part of the long-range study of 1966. The end product of the staff teams are special analyses which stand as independent entities setting forth priorities and proposed budgets for the areas covered by the decision unit.

The second level of priority setting and budgeting involves the heads and key managers of the interested agencies (ARS, CSRS, and ERS). The third and very crucial level is in the Secretary's Office where priorities and proposed budgets from all agencies are brought together and merged. Awareness of the attitudes of OMB and Congress is important at all budgeting levels.

The budgeting process and setting of priorities for research in the USDA has grown to become a very large, year round, effort requiring participation of a great many high level scientists. The process starts with the identification of all research projects under the CRIS system. This has been further refined and computerized into the PARIS system. This documentation of all research projects supported by State and Federal funds is a large accomplishment. It provides a means for avoiding duplication and for obtaining an overview of research effort in various fields, including PHT research. These systems as well as the Users Advisory Board and the Joint Council serve as a means for coordinating Federal and State programs. Similar documentation of agriculturally-related research performed by private industry is not available and without it, estimates of the amount and kinds of PHT research done by private industry are of questionable validity.

The size of the investment and priorities for PHT research proposed in the budget are determined finally by negotiations between the Secretary's Office and OMB. The fate of a project in the budget will depend on the importance they attach to improving the efficiency of post harvest and marketing practices as compared with other needs in USDA. Whether or not funds are eventually appropriated depends, of course, on the relative importance Congress attaches to the projects proposed as compared to other national needs.

The scientists in the USDA are aware of the great amount of professional time and effort that is now devoted to the budgeting process, and many feel that there is little to show for it except excellent documentation and any satisfaction that can be derived from being able to say that everybody was consulted. Many know from experience that the major part of this vast amount of documentation never plays a significant role in a given year's budget process, never reaches the high point of decision, never is used in the supporting statements that evantually accompany the budget to Congress. (It has been said in defense, that all of this elaborate documentation is just as necessary for those projects that are too weak or unimportant to be considered seriously in budgeting as it is to justify the strong, important projects that are.) Many also know from experience that the "strong" projects that survive in the budget often disappear with a stroke of the pen in the appropriation process thus nullifying the effort that went into the preparation of the justification for it, whether it was cursory or extensive.

Thus, it would seem that a lot of expensive manpower is currently being expended polishing logs before they go to the saw mill. It would appear to be more realistic and more cost-effective, not to generate elaborate and presumably precise analyses which, at best, are of transitory accuracy and usefulness, but to derive and adopt simpler procedures that would be fully adequate in light of the practicalities of the budgeting and appropriation processes. Such a change would spare the funds, as well as the scientific manpower, for the creative work they are trained to do.

A Plan for Deciding Who Should Support and Who Should Perform PHT Research

In all of the history of research in agriculture, no fixed pattern has developed with respect to the kinds of research the USDA, the SAES, and the industry perform and no "principle" has been apparent in determining the role of each. Decisions as to where research is done in the public sector (which is, for the most part, the only sector where such decisions have any meaning), have invariably been arrived at ad hoc by discussion and agreement between the parties concerned. The kind of administrative diplomacy required to reach such agreements and the staff required to practice it have, as indicated above, reached high levels of complexity in USDA and SAES. Such decisions are arbitrary, expedient, inconsistent from year-to-year, and more influenced by the pressures of the moment than by uniform, long-range guidelines or principles. Lacking an accepted rationale for doing differently, these practices will likely continue.

It should be possible, however, to arrive at a rational and practical plan for assignment of roles to those who conduct PHT research. Admittedly, any such plan would also have to be arrived at arbitrarily and by agreement, but once enunciated, made public, and used, it would make clearer to all concerned the basis and logic of certain program decisions, encourage USDA and SAES to focus on the roles expected of them rather than to "play the field", and permit periodic re-examination of the plan as flaws become apparent with time and experience. Ideally, application of the plan and the working guidelines that should flow from it, should result in clear enough delineation of roles that uncertainties concerning where research should be done and who should pay for it would be the exception rather than the rule.

There are obvious alternatives for financing and locating PHT research but there are cogent reasons that the cost and workload, as now shared by USDA, SAES, and private industry, is the alternative that should continue to be practiced in the future. There is no way* that private industry can be persuaded, let alone directed, to assume responsibility for fulfilling all of the research and development needs in PHT that are necessary in the national interest. Professional staffs and facilities in industry are geared to do the kind of research and development that has good prospects for short-term pay off. Much of this is expensive, large-scale pilot plant or factory scale experimentation and market testing of food and kindred products for which industry was estimated to spend about $300 million in 1975. In the same year, USDA and SAES together spent about $165 million for PHT research, much of it of basic or pioneering nature that has little appeal for industry. Industry could hardly be expected to finance or perform that kind of research or to do it well. Of the funds spent on PHT research in the public sector, about 52% are Federal funds. To shift the total, or even a major part of the burden to the states, thus requiring the states to pay disproportionately for benefits to all of the people of the United States, would be neither reasonable nor tolerable. It follows then, that all three should have a financial input but that USDA should continue to bear the major financial responsibility for the PHT research that is supported by public funds.

If we assume, then, that the three performers, USDA, SAES, and private industry, will and should continue to conduct PHT research --private industry primarily with its own resources, USDA primarily with Federal funds, and SAES with State, Federal, and private funds. The roles of the performers are generally more complementary than competitive and, to a considerable extent there is coordination of programs, particularly those of SAES and USDA. Federal funds are the only ones over which national planners in USDA can exercise control, even though the nature and potential of contributions to national goals of programs supported by State and private funds can and should be recognized and appropriate adjustments made for them in planning and distribution of workload and apportionment of Federal funds. Thus, clarifying roles of the three performers involves consideration of two questions: (a) what criteria should be used for distributing the workload among the performers and (b) what criteria should be used for apportionment of Federal funds.

(a) Under the Hatch Act (passed by Congress on March 2, 1887) and the Research and Marketing Act of 1946 (PL 79-733), the SAES conduct research on local, state, and (cooperatively with one or more states) on regional problems, but they have no mandate to conduct research on problems of national import, even though research on state or regional aspects contribute to the solution of national problems. The private sector conducts research in areas that have potential for propietary advantage, sometimes with significant benefits to agriculture or the consumer generally. Only USDA (the "Organic Act" of agriculture was signed by President Abraham Lincoln, May 15, 1862) has responsibility for assuring that PHT research directed at problem-solving in the national interest is conducted, and in the process, must always address local and regional aspects of the overall problem and may develop products or processes that private industry will find it profitable to adopt.

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* A device sometimes tried by budget planners, but rarely successfully, is to "deal Government out" of research in a particular area by not budgeting it, when it is believed that private industry will have sufficient interest in its continuation to support it. In such instances, history shows that restoration of public funds, particularly Federal funds, invariably occurs in the appropriation process.

Thus, given present laws, the PHT workload tends to distribute itself quite logically among the three performers. The Federal Government, either intra- or extramurally, must give highest priority to problems of national significance, and as part of this responsibility, maintain a constant awareness of and take into account in planning, the contributions the States and private industry are making toward these national objectives. Private industry does research on those aspects of PHT which have profit potential, particularly in the short-term, conscious always of the nature and status of ongoing Federal and State research that may advance their goals. The SAES must give highest priority to problems of concern to the State and next to those of the region of which they are part.

These roles of the performers have historic precedent and the distribution of the research workload in the manner described still appears to be sound today. Indeed, the special facilities and skills that have evolved in the public (Federal and SAES) and private sectors to do research on "their kind" of problems, are reflections of the general practicality and acceptance of this distribution. It would seem reasonable that PHT research should be performed where the facilities and staff competence are best suited to the job*. The following paragraphs identify the principal performers of PHT research and provide an approximate catalogue of the capabilities of each. The USDA and SAES program planners and managers would who would be making decisions have exact knowledge of Federal and State staff and facility availability and have only slightly less detailed knowledge concerning any unique competence or facilities available in private industry, private research instituions, and in nonagricultural academia.

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* Some critics have contended that following such a policy would freeze the division of effort among current performers and that they would remain entrenched in their little ruts for evermore. That could occur if the rules for locating performers were mandates rather than guidelines as this proposal intends. Since there will continue to be considerable freedom for all participants within the guidelines, new centers of excellence would be expected to arise from time to time and become candidates for support of their kind of PHT research.

---The Agricultural Research Service (ARS) is the largest performer of post harvest research on food and kindred products. ARS operates the regional utilization laboratories and also performs PHT research at a number of other locations. It maintains a pool of talent fully capable of addressing and resolving problems related to food preservation, processing, quality, safety, storage and distribution at the international, national, and regional levels. It has developed and fosters a long, amicable, and productive cooperative relationship with private industry. ARS has unique facilities, equipment, and instruments in major laboratories for conducting research on major problems of national importance which no one State or private group has the resources or need to solve; it provides research to support USDA regulatory agencies; it promotes export market of U.S. commodities by (a) research on improved packaging, shipping, and preservatives, and has unique capability for evaluating these technologies in its laboratories maintained overseas, and (b) providing staff members who are experts in processing, properties, and uses of agricultural commodities and their derived products to assist U.S. growers and processor associations introduce U.S. farm products in foreign markets; it conducts research and development to facilitate international food assistance programs of the U.S. Government; it has scientific staff of such size and such diverse disciplines that it can quickly organize teams of the size and composition needed to adequately attack emerging problems of national priority; it is unique in having many of the special facilities and much of the expertise required for conducting basic and applied research on nonfood uses of agricultural commodities.

---The Economic Research Service (ERS) is the dominant performer in USDA of research related to the economics of ag-food marketing. ERS, together with the Statistical Reporting Service, provides most of the data, analyses, and rationale undergirding ag-food policy. They also provide government and industry with current and outlook information regarding domestic and foreign demand, production, supply, utilization, and price. ERS may also address longer range issues with regard to resources, development, structure, efficiency, performance, and people.

---The Land Grant Institutions (SAES) complement and supplement the activities of the USDA agencies just described and have, generally, professional personnel of quite similar training and requisite facilities. However, the Land Grant Institutions are tri-functional. In addition to research, these institutions are charged with on-campus and extension education. The primary purpose of extension education is to widely and fully disseminate knowledge and technologies as they flow from research activities of both Federal agencies and State institutions. Research activities that might otherwise be performed by Federal agencies or private industry are necessary to graduate training and a continuous replenishment of scientific and professional talent.

---Private industries are the sole possessors of the full-scale equipment and facilities necessary for reducing research ideas to commercial practice. Moreover, most scientific personnel of industry are especially selected for the kinds of knowledge and skills that are required for the successful application of research results and the development of products and processes rather than the kinds that excell at basic research and discovery. Not all industries can afford the expense of research and development departments and often rely on cooperative ventures with public agencies to improve products and processes. Private industry uses the knowledge flowing from the Land Grant Institutions and Federal laboratories as well as the scientific talent from the universities for their principal purposes--product development and quality control. Most industry research and development activities in food and kindred products are designed to develop and market new or improved products, but some effort may be directed to increasing efficiency or cost cutting. Private research and development are motivated by profit potential and the opportunity to gain an edge over competitors. Little, if any, of the results of private research are likely to be shared with other firms.

(b) PHT research expenditures by each participant should be in proportion to the benefits each expects to derive. Admittedly, benefits to any one of the participants often results in benefits to the other two. Only the simplest cases are obvious. If one state should be the major beneficiary, relatively heavy support of the research by that state legislature and use of Hatch Act funds would be expected. If the states of a region are major beneficiaries, relatively strong support by the states of the region would be warranted. Since industrial research and development to fabricate a new product or improve an existing product or process is rarely made public and is of primary benefit to owner or stockholders, it is clearly a responsibility of private industry. In the case of public research on post harvest problems where all in the U.S., as well as the local populace, may benefit by improvements and innovations, the degree of responsibility of each principal is less evident but the consideration in Section Three of this report with respect to beneficiaries of publicly supported research is relevant. Moreover, if consideration can be given and decisions made, as they now are annually in USDA/SAES, by weighting various factors and arriving at priority lists of urgent problems facing agriculture, the same system (and personnel) could evolve procedures for weighting the benefits accruing the three principals and establish a fair proportion of the cost to be borne by each. Included in the weighting, of course, should be such considerations as national need in times of domestic or international crises, threats to the public health, data and method needs for support of Federal regulatory programs, and need to improve America's competitive position abroad.

To accomplish the scientific workload, Federal and State funds can be used in-house and extramurally by both the USDA and the states, and states have as well, funds through Federal formula grants and, on occasion, funds from private sources. Moreover, factors such as which candidate for funds is closest to the problem, which can complete the research the quickest, which can do the research at least cost, and which of the public agencies generated the idea or received requests to undertake the research, can be worked into the equation in the decision-making process. Thus, Federal or State planners and managers have many options which are quite likely now considered and should continue to be considered in making program decisions. However, without question, the existence of continuing in-house staffs of bench scientists at both Federal and State institutions, is bound to influence the decisions made annually concerning the placement of research funds, thus reducing the number of options actually utilized. There appears to be no ready means for avoiding this if, indeed, it should be avoided. A strong case can be made for maintaining enduring scientific capability at Federal and State levels. This means maintaining a reasonable continuity in in-house programs, without which quality of staff deteriorates.

Admittedly, the plan and procedures suggested above may be no less cumbersome and complex, at least initially, than the existing system. However, their adoption could help clarify some long-standing areas of confusion between USDA and SAES with respect to funding and programming and point the way to readjustments that could be mutually beneficial. In time, the process could conceivably be simplified, but schemes for simplification of such a system involving, as it must, the resources and the individual goals, preferences, and biases of 50 states, the Federal establishment, and countless private entrepreneurs, are easily shattered. For example, such notions (for simplicity's sake) as centering all PHT research on a given crop, or all PHT research involving chemistry or engineering, in either USDA or one or a group of SAES, are technologically unsound and would be politically untenable. There appears to be no alternative yet conceived (except a return to the autocracies of many years ago) to accomplish this except by the democratic process which means accepting the complexity that is inevitable when plans and decisions must be made by committee.

Some Observations on Basic, Applied, and Developmental Research

A traditional concept of division of research effort among the public and private participants has been that most (even all) applied research and development activities should be done by private industry and that public agencies should confine themselves to basic research. Experience has shown that a hard line cannot be drawn without denying the small, have-not industry the assistance of public agencies in applied and developmental areas, and without tempting big industry to rely too heavily on public agencies to do special basic studies they should be doing and paying for. The question of division of basic, applied, and developmental studies needs further examination.

There are approximately the same number of definitions of basic and applied research as there are those who have addressed the subject. Broadly, basic research may be defined as activities directed to understanding the nature of systems. The systems may be physical, biological, mechanical, economic, social, or political. Basic research is directed to specifying and quantifying interrelationships in a cause-effect context. It is concerned with theoretical concepts, formulating testable hypotheses and testing them,and with enunciating laws and principles. Progress in basic research depends largely on the wisdom, ingenuity, and imagination of the individual performing it. Thus, to function effectively, basic research cannot be highly structured and demands for accountability should be minimal. Planners, managers, and administrators need to limit their roles to determining the level of support for basic research and identifying the individuals with the most appropriate professional background and the greatest potential to perform it. Basic research is almost universally transferable.

Applied research is directed to modifications of systems to achieve greater efficiency or specific goals. In production research, the goals might be maximum yields, optimum economic yields (maximum net revenue), maximum or economic optimum feed efficiency, minimum loss from pests. In the post harvest sector, the goals might include minimum loss in marketing channels, maximum preservation of quality, optimum storage strategy, optimum distribution patterns, maximum net revenue to participants, minimum cost to consumers, optimum allocation of resources. Applied research is amenable to a degree of structuring, planning, and coordination and accountability is feasible and to be expected. Issues of necessary replication versus unnecessary duplication come into play more frequently in applied than in basic research. Transferability of results becomes more important in some kinds of applied than in basic research, as for example, much of the applied research in crop production is not transferable among locations due to soil, climate, terrain, and light differences.

Many activities may be included in product and process development. Pilot studies or the testing of a technology on a small-scale for technical and economic feasibility, is included in development. These studies include such activities as identifying and removing constraints (debugging), determining equipment needs and optimum operating conditions, and providing a sound basis for estimating manufacturing costs prior to implementation of a new technology requiring large capital investment. Market testing prior to commercial production would also be included in industrial development costs and quality control costs might be included as well. Most of product development is in the private sector.

A solution for a problem--put out a fire--in the ag-food sector is relatively simple if knowledge, available from previously completed research, suggests ideas that can be tested for practicability and economic feasibility. If sensible ideas for solution of a problem do not suggest themselves or if ways need to be found for removing obstacles to a possible solution, then applied research with the objective of exploring new ways and means or for overcoming obstacles should be undertaken. If such applied research fails in a reasonable period of time to point to possible solutions, it may be necessary, through basic research, to obtain a better understanding of the cause(s) and mechanisms involved in the problem. The knowledge accumulated thereby may suggest new avenues for exploratory applied research directed toward solution of the problem but may also make possible the eventual solution of problems yet to emerge.

Development of a product or process or a solution to a problem cannot be undertaken without the adequate underpinning of the knowledge gained from applied, and if necessary, basic research. That's why the research components of organizations like USDA and SAES, which are mission-oriented, strive to have funds to support a continuing mix of applied and basic research and thus approach the kind of readiness needed if timely solutions are to be forthcoming for problems that are continually arising. Experience has shown that an adequate core of basic and applied research should continue to be supported even when an occasional dearth of pressing problems prompts some to challenge the need for its continuance. It is foolhardy to remove the "Caution, Cliff!" sign at the end of the road just because, lately, no one has driven over the edge.

How big the basic part of a research program should be compared to applied, can't be answered categorically since the relative amounts of each are influenced by a host of factors. However, an applied research program wholly without a basic research component is self-sterilizing. Its knowledge base will not long support applied research aimed at problem solving and it is unrealistic to expect that the basic research of others will, fortuitously, be an adequate substitute. Research organizations with strong basic research components attract and retain competent professional personnel. In the ag-food sector, where the problems are predominantly biological--an area in which relatively little is still known of causes and mechanisms--a continuing flow of new revelations from basic research is vital. A basic research level of 40% of total research is a realistic goal but one that has rarely been achieved.

What Encouragement Do Scientists Need?

The requirements for the encouragement of those who conduct PHT as well as all research, whether applied or basic, have many common elements. Certainly, adequate funding is important so that space, equipment, and supplies are not limiting factors and so that support staff is available to obviate the need for wasting professionals' time on routine tasks. Scientists regard most of the trappings of administration as a gross waste of time and money--too frequent report writing, too frequent staff meetings, lessons in management, preparation of budget justifications--and means should be found to spare them these chores which they do neither gracefully nor well. The time saved from not having to do these chores themselves as well as the time saved by eliminating the reasons for complaining about them before and after the fact, is better spent doing the things the scientist is trained to do. With leaders, not managers, at the key operating levels of the organization--leaders who can establish a symbiotic relationship with those led and who are respected in the scientific community, many of these deterrents to sustaining good research and high morale will be recognized and pursued with the persistence it takes to have them eliminated or minimized. This is all the encouragement most good professionals need.

The Case for a Strong USDA

There are those who contend, periodically with vigor, that much now done by the Federal Government should be done by the states or private industry. Regulatory programs are particularly favored for shifting but research has not been ignored. Some proponents of the latter group, while conceding that USDA should do some research, are not convinced it should do as much as it does now. Some aspects of the size question--how big and diverse should USDA's research program be--will be considered in Section Six of this report but the philosophical aspects will be discussed separately here to give them the prominence they deserve.

One should recognize how important it is that the President of the United States have a Department of Agriculture and that its Secretary have a strong intramural research arm.

The products of American agriculture are essential to the Nation's physical welfare and, in recent years and for the foreseeable future, are our most important asset in world trade. Agriculture has critical impact on all of the people, important impact on many industries, and, considering the many who grow, transport, process, store, and merchandise agricultural raw materials and products, significant impact on the labor market. What happens in and to agriculture, therefore, is of prime concern to a President of the United States.

To assure that he is apprised of agricultural events and is in a position to anticipate problems and react to meet and resolve them, the President needs competent, continuous, and timely advice and guidance and a means to administer programs he or the Congress mandate. A Department of Agriculture with a professional staff of the proper disciplinary mix and the machinery to seek, analyze, and project relevant information and act upon it, has demonstrated over more than a century that it is effective as such a source and means. The research innovation of this staff has permitted Secretaries of Agriculture to discharge their major responsibility--to assure protection of the American food and fiber supply and achieve the enhanced efficiency in the agricultural system that results in lower real prices to consumers.

Private agricultural research is not directable by the Secretary of Agriculture and is of unpredictable timeliness and relevance to national needs both qualitatively and quantitatively. Research of the SAES, considering present close USDA/SAES relations, is likely to be consistent with national goals, but the nature of the research of the SAES has traditionally lent itself more to persuasion than to direction by the Secretary of Agriculture.

To a Secretary of Agriculture, having an intramural research establishment has distinct advantages over purchasing innovative talent extramurally. A research establishment, meaning scientists, engineers, economists, and capable professional leaders who are actively engaged in research and its direction, provides the Secretary with advisors who maintain their expertise and virility by active participation in research and by making peer-reviewed contributions at the moving frontiers of science and technology. Not nearly as good is the advice of small cadres of post-prime professionals who learn by monitoring extramural programs.

An intramural research establishment is "there" when the Secretary needs to call upon it to address problems requiring solution in the national interest for which the States and industry have no incentive and, on occasion, no competence. An intramural research establishment can provide continuity in program areas where the nature of the problem demands it and where the states and private industry find it unattractive for various reasons to provide such continuity. An intramural research establishment develops a national rather than a provincial attitude towards agriculture.

These arguments, as compelling as they would seem to be are often discounted by some as the "self-serving kind expected of professional bureaucrats". However, these so-called bureaucrats are content to let the record, which illustrates the breadth, depth, soundness, and value of achievements in which a strong USDA had played a prominent role, speak for itself. There is no doubt that the contributions of strong USDA in the past in the interest of the farmer and all of the people will continue to be made by strong USDA in the future. We have had no experience trying to get along without one.

Section Five

METHODS FOR EVALUATING THE QUALITY OF PHT RESEARCH

Much of this section, as it applies to PHT research was derived from papers by B.T. Shaw, "The Use of Quality and Quantity of Publications as Criteria for Evaluating Scientists and the Quality of Research," USDA Miscellaneous Publication 1041, 1967, and OTA Commissioned Paper No. 6, Work Group II, by Evenson and Wright, "An Evaluation of Methods for Examining the Quality of Agricultural Research." Additional details can be obtained from these papers.

General Considerations

The ultimate value of research and development is the performance of the sector to which the research and development activities are directed. In this regard, the performance of the food sector in the United States--food production, processing, and distribution--is unquestionably a model of success for our own economy and that of the world. It is difficult to place dollar values on the abundance of high quality food universally available to American consumers at relatively low cost. By any objective measure this is an achievement that has never been equaled at any other time or place. The marvel of the American food sector is a result of scientific research, technical innovation, availability of capital, and the incentives provided by a free enterprise exchange system. Compared to what has been accomplished in medical care and energy in the United States, accomplishments in the agricultural sector rank most favorably. However, such practical successes are usually apparent only long after the research that spawned them has been completed and are often the resultant of several research successes and failures. It would be most useful to have a reliable means for assessing research quality in the interim.

Broadly, there are two kinds of research, basic and applied. Basic research produces new knowledge such as discoveries, isolations, elucidations of mechanisms, methods of detection and measurement, and synthesis, all of intangible value since their practical applications are not yet known. Applied research results in new or improved products or processes. Examples are disease resistant cultivars of plants, frozen foods, and wash-wear cottons. Most are of tangible value because they can be observed and evaluated in the market place.

There are also two kinds of performers of research, public and private. While much of publicly sponsored research is designed to solve problems, it is a prime responsibility of public agencies to do the kind of research that provides basic knowledge. Research results of public agencies are generally published and made available to other scientists, the industry, and the public. Such publication is evidence of activity and progress and citation by peers provides an indication of importance. However, publications (papers in scientific journals, books, patents) vary widely with respect to originality, depth, substance, and relevance. Moreover, while citation is evidence of peer awareness of the published research, reaction to the research itself may be either positive or negative. Any use of publications as a measurement of quality needs to take these factors into account. By contrast, private research, including that in PHT, is directed largely to the ultimate development of products and their improvement and merchandizing. Much of this activity results in patents or in "trade secrets." Because patents provide the innovator with some protection in the market, they are conducive to market structure departing from pure competition; they are made available to the public only at a price. To the extent that private industry publishes any of its research results, it is contributing to public knowledge, but assessment of the quality of these results is subject to consideration of the same factors cited above.

There are no accepted measures of the value of basic research. Entwined in the process of evaluating basic research results, is the evaluation of the scientists who do the work. Certainly the two are not independent. Some of the criteria used in judging the quality of research are:

(1) Thoroughness in the planning of the research and a good knowledge of the scientific literature pertaining to the project.

(2) Method of attacking the problem, the imagination and ingenuity used in doing the research.

(3) The results obtained and their usefulness in solving the problem or increasing basic knowledge.

(4) Publications resulting from the research, the acceptance by peers, and citations by other workers.

(5) The cost of the research in manpower and money in relation to the benefits derived.

These criteria hold good for applied as well as for basic research, but there are various additional measures of the value of a new product or process. How much economic value does it create? Does it improve efficiency as compared with an existing product or process? Does it prolong or save lives or alleviate pain and discomfort? Does it eliminate or modify onerous labor? Does it save time? Does it minimize waste? Does it avoid pollution?

While the dollar value of the product or process or the value added can be arrived at very accurately in some cases, many of the "values" indicated above can be measured only subjectively.

Evaluation of PHT Research Based on Shaw

B. T. Shaw, former Administrator of the Agricultural Research Service, analyzed the use of publications as criteria for evaluating scientists and the quality of research. Three approaches were considered in the analysis: 1) ranking by a peer group of scientists reading the publication, 2) ranking by number of publications, and 3) ranking by the publication outlet. Ranking by number and outlet were found to be unsatisfactory. While ranking by a peer group reading of the papers was regarded as the best method, to do this for a single year would not have been feasible since it would have required reading some 3500 ARS publications. As a compromise, each scientist was asked to rank his own publications, using the following guidelines:

Rank Order 100-81. Original research having very great impact on science, agriculture, and general welfare. Papers falling into this category would be discussed in all histories of science pertaining to a given field. The research would be cited in the writings of most, if not all, scientists doing related work.

Rank Order 80-61. Original research having great impact on science, agriculture, and general welfare. These papers would frequently be cited in the writings of other scientists and the authors would be invited to present work in scientific symposia and review publications and would be given awards for outstanding work.

Rank Order 60-51. Original research having moderate to limited impact on science, agriculture, and general welfare. Papers in the top of this range would be cited frequently in writings of other scientists.

Rank Order 50-41. Reviews of research for scientists.

Rank Order 40-31. Reviews of research for laymen.

Division Directors were then asked to rank the 118 papers covering many years of agricultural research using the above criteria. There were 10 papers ranked 95-100; one, a patent for the production of penicillin, and another, a paper on separation and identification of some terpenes, came from what is now called PHT research. Of the 105 papers and patents ranked 55 or higher, there were 36 in the PHT research category. Thus, of the papers chosen by a peer group as having limited to very great impact, a third were in the area of PHT research; of these selected as having great to very great impact, one half were on PHT research.

In considering these high scores for PHT research, it is significant that it was never supported by more than 25% of the total funds for research in ARS.

Evaluation of PHT Research Based on Evenson and Wright

Evenson and wright chose two measures of research output as quality indicators in a study of the quality of PHT research conducted in USDA and SAES. These indicators were 1) patents selected as a measure of the quality of research directed toward invention and 2) citations of publications in peer-reviewed journals as a quality measure of research that leads to new knowledge and to new technology that may not be patentable.

The analysis of patents was limited to USDA patents issued to scientists at the four Regional Utilization Research Centers* located in Peoria, Philadelphia, New Orleans, and Berkeley. Evenson and Wright's difficulty in finding many SAES patents suggested to them that SAES units produced few patentable inventions. Data were collected for all USDA patents in four PHT fields--food, textiles, chemicals, and other--for the years 1966-1968 and 1977-1979; for a sample of 80 patents of private U.S. companies; and for 61 patents issued to foreign firms in the food and textile fields. As indication of quality, comparisons were made of citations of these patents in patents issued subsequently. For example, USDA patents were cited as "next best art" in 19% of the private patents, indicating that USDA patents in PHT research were significant in the invention structure of the private sector. The number of times that USDA patents in the food and textile fields issued in 1966-1968 were cited in subsequent patents was comparable to similar citations for private patents; average number of citations for food patents was 2.36 for USDA, 2.39 for private firms; for textile patents, USDA 2.18 and for private firms 3.45. Another comparison of USDA and private patents was the percentage of patents issued in 1966-1968 that had no subsequent citations. For USDA food and textile patents, these percentages were 22.0 and 34.7, respectively; for private patents, the corresponding percentages were 30.0 and 18.8.

Citations of publications were considered by Evenson and Wright to be a better measure of quality of PHT research than patent citations. Data for SAES were limited to citations of the publications of project principal investigators; for USDA, citations were used for all persons who authored or co-authored an article appearing in the list of publications of each of the four Regional Research Centers as well as six smaller USDA laboratories engaged in PHT research. Statistical analysis of these data showed no difference in the efficiency of USDA and SAES research laboratories in performing quality PHT research by their principal investigators. A more comprehensive comparison between 1966 and

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* These Centers are now a part of PHT research.

1978 of citations of USDA Regional Research Center articles published in peer-reviewed journals, indicated no decrease in high-quality research per scientific-man-year (SMY) over that 13-year period. The Center having the lowest journal citation per SMY had, however, the strongest performance in patenting indicating a different research orientation at that Center.

Evenson and Wright pointed out that patents and publications have limitations as measures of research quality. They indicated the need to relate such output measures to some economic measure of the quality of the research. It can be argued that the examples of accomplishments in PHT research discussed in Section One of this report, demonstrate the substantial economic return from this research despite the fact that this list is not intended to be comprehensive.

A generally accepted method for evaluating the quality of research is yet to be derived.

Section Six

FUTURE POTENTIAL FOR PHT RESEARCH AND PROPOSED LEVEL OF SUPPORT

Research in post harvest technology has not fared well with the decision-makers in recent years. Heavier emphasis has been given instead to natural resources (conservation), energy (conservation and alternate sources), plant biology (photosynthetic efficiency, stress tolerance, and nitrogen fixation), and to environmental problems. While there is no denying the importance of these issues and concerns, the fabrication, preservation, and distribution of foods are at least as vital to the welfare of American consumers; maintenance of quality in nonfood products based on agricultural raw materials and creation of new ones, are also important to the American economy. In fact, the potential for reversing or retarding the relentless upward pressure on the cost of food and kindred products is greatest in the post harvest sector which accounts for about two-thirds of the consumers' costs for these products. In light of all this, at what level should PHT research be supported?

Optimum Funding Level for PHT Research

Most of this subsection deals with determining the optimum level of funding of PHT research in USDA and SAES. Determining the level of PHT research in industry requires only the briefest mention since it is clearly the prerogative of each firm. To say, as some have, that government should do less and that industry would then do more to fill voids, ignores the basic differences between them. Profit-motivated industry and public service-motivated government march to different drummers. Since industry's and government's objectives in PHT are likely to coincide only fortuitously, government must continue to be responsible for research deemed to be necessary in the public interest.

Planning and decision-making with respect to apportioning funds in the public agricultural research system will, of course, be strongly influenced by the size of the pie known to be, or likely to be, available for slicing and distribution. In 1979, PHT research funds available annually in USDA and SAES totalled about $210 million, of which 52% was USDA's. Industrial funds devoted to PHT research and development amounted to at least $300 million annually, the amount estimated to be spent on food research. No figures are available for industrial PHT research expenditures for nonfood purposes, i.e., textiles, industrial fats and oils, leather, and chemicals derived from agricultural raw materials. Is this annual research investment enough to permit adequate attention to current and potential national and regional programs in PHT? If not, how much should the total be? Are there reliable indicators of proper size? Is the present division of funds between USDA and SAES appropriate considering national, regional, and local interests? Is industry doing enough? Are program content and balance what they should be? Since these questions are interdependent, the answers must also be.

In general, an economic optimum is attained when output is expanded to the point where marginal cost is equal to marginal revenue. This principle is applied by progressive industries with research components who find it profitable to reinvest a fraction of their gross in research and development. This principle also applies to public funding in the context that funding should increase at the margin to the point where benefits and costs are equal. Funding of PHT research can be increased in marginal increments and measured rather precisely. Benefits stemming from PHT research, however, cannot be measured precisely. Consequently, the optimum level of funding cannot be determined with precision.

This is a serious matter. Our inability to say unequivocally how big the PHT research program should be to be adequate, and to support our contentions with convincing evidence, weakens the presentation of budget requests--makes them seem less important or less urgent, less compelling than other activities competing for funds in the national and state budgets. To compound the problem, failure to define a "critical mass" of PHT research activity (that is, a program can be so small that it is not much better than no program at all), makes it vulnerable to challenge and fund erosion.

It is rather obvious that continuous financial support is necessary to maintain a research capability. Inasmuch as salaries of professional personnel are the largest costs in research, reduction in salaries must often be employed when funds are reduced, even to the point of neglecting to grant cost of living increases. Other alternatives are reduction in the number of personnel, postponing maintainance of buildings and equipment, and/or foregoing the purchase of desirable research supplies and new equipment. The consequences of these actions, when and if they become necessary, are significant. Reduction in salaries are generally signals to professional personnel, whether in the public or private sector, to seek alternate employment and the existence of persistently low salaries and wages encourage noncommitted younger persons to pursue other careers. Obviously, protracted continuation of such circumstances ultimately result in a national shortage of scientifically trained personnel. Neglect of buildings and equipment is also costly in the long run.

Short-term research funding--primarily contracts and grants--can substitute for in-house personnel temporarily, but to maintain expertise at the Federal level, there must be the in-house staff continuity that adequate, stable financing permits. In-house expertise cannot be established through contracting where the professional actors change constantly and have no continuing responsibility.

Government funding, like levels of taxation, is based on the collective judgment of legislative bodies. Ideally, objectivity and precision in estimating needs and benefits contributes to better decisions both with regard to taxation and to the allocation of funds thus derived to support expenditures in the public interest. But legislative bodies need factual information and best advice available to guide them. Some of the problems involved in providing such information and advice succinctly and convincingly warrant consideration.

In the case of PHT research, benefits accrue to consumers (the public) in several different forms including: 1) prices to consumers that are lower than they would otherwise be; 2) increased volume of product at the retail level; 3) increased safety in foods; 4) increased variety in foods which contributes to gustatory satisfaction and insures adequate levels of vitamins, minerals, and nutrients; 5) improved health and medical costs lower than they would otherwise be; 6) a cleaner and more aesthetically pleasant environment; 7) costs lower than they would otherwise be for food stamps and other government food aid programs; 8) a reduced rate of price inflation; 9) an improved military capability and reduction in cost; 10) an improved international trade balance; 11) increased contribution to alleviation of hunger and malnutrition worldwide; 12) increased efficiency in the use of energy; and 13) increased complementarity of food production and energy production.

As impressive as this array of benefits is, estimating their dollar value is rather illusive. Lower prices and increased quantities can theoretically be estimated in terms of economic surplus. However, the level of prices and quantities related to varying levels of PHT research funding cannot be even roughly determined. Such benefits as reduced health costs, government food aid costs, and military food costs, also carry dollar values. But again, the values that can be associated with varying levels of PHT research funding can only be "guestimated". Other benefits such as environmental quality, social tranquality, and individual satisfaction are not priced in the market, yet there are costs associated with providing these kinds of benefits to the public.

One must conclude that this approach--finding the point at which marginal costs equal marginal benefits--as the principal means for justifying the level of funding of PHT research is not practicable.

However, a modification of this appraoch, one that uses the relatively sound industry estimates of the commercial value of those PHT research developments of the immediate past that have been adopted by industry, and relating the total value to the cumulative cost of funding the USDA/SAES research effort in PHT is, we believe, a valid-means of relating benefits to research costs. Since the dollar value of the benefits estimated in this manner far exceeds the total cost of the research that spawned them, it can be contended that the recent annual PHT funding levels have paid-off many times over. It can be argued then, that funding PHT research at least at the annual level of the immediate past, is fully justifiable in terms of benefits to the American people. It may also be contended that increased levels of funding for PHT research would quite likely be repaid in like manner. In other words, if the publicly supported PHT research enterprise with its most successful record were a private concern, one would find little difficulty in selling stock in it.

The history of the past decade or two reveals that (see Section Two of this report), as a proportion of the total Federal research expenditures, PHT research ranged from 32% in the mid-1960's to 26% in the late 1970's. Corresponding figures for the SAES were 17% and 15%. The percentage of the total public funding that is devoted to PHT research should be considerably greater than this, perhaps as much as 60% of the total since this is the value created in the ag-food sector attributable to the off-farm activities toward which PHT research is directed. However, in view of the many variables that must be considered in the annual budgeting process, it is more realistic to suggest only that Federal PHT research funding should be much higher than it is. It should be added that existing Federal facilities could accommodate, and present scientific leadership could marshal an effective program utilizing additional funds. A proportionate increase should also occur in the SAES. It can be predicted with confidence that by devoting additional PHT research funds to the problem areas described in the following paragraphs, their great potential will be realized.

Potentials in Basic Studies on Development of New Foods

The greatest potential for conserving resources, especially reduction in soil erosion and reduced water requirements, is in developing vegetable-based, high-protein food. Developing high-protein foods directly from plant sources, that are nutritionally sound and acceptable to consumers, would increase the human food potential for grain and soybeans by 10-fold compared to producing foods with monogastric animals. This does not, of course, negate the role of ruminant animals in converting forages and waste materials into desirable food. By-passing monogastric animals in a larger portion of the food chain would also substantially reduce the energy requirements of the food system. There is a very great potential in developing nutritionally sound, acceptable foods, and research emphasis should be on nutritional soundness and on basic studies on the identification of methods of measurement of the physical chemical and structural factors that determine texture, cooking, and masticatory properties. Research can also point the way to the development of consumer acceptable foods that meet evolving nutritional guidelines for healthful levels and kinds of salt, sugar, fat, protein, and additives.

Increased consumer concern for the nutritional value, health, and safety aspects of foods will continue to have important effects on post harvest research and technology. Maximum retention of nutrients will receive increased emphasis in food processing and in the distribution of fresh foods to the consumer. More research will be devoted to food composition, and particularly to the identification of naturally occurring deleterious substances (anti-nutrients, mutagens, carcinogens, etc.) and those formed in processing (also in home preparation), so that means can be devised to limit, remove, or inactivate these substances in foods. Varietal differences in composition of food plants with respect to such undesirable components will need to be explored. Further, as nutrition research establishes optimal intake levels of various common food constituents that affect product quality and consumer acceptance, there will be incentive to develop new products in which the constituent in question has been reduced or removed without affecting product quality.

Potentials in Research on Food Preservation

Reduction of losses in food in the marketing continuum would contribute to resource and energy conservation, reduction in environmental pollution and reduced pressure on consumer food costs. Moreover, current food preservation is highly dependent on mechanical refrigeration which consumes appreciable amounts of energy. Thus, urban food supplies are highly vulnerable to disruptions in electric power due to shortages of energy sources--weather, domestic strife and alien attack. Research aimed at discovering alternate methods of food preservation, including the use of safe, effective chemicals, would reduce energy requirements and reduce the vulnerability of the urban food supply. Improved methods for the preservation of fresh fruits and vegetables in the distribution system would enhance their appeal and improve their essential nutritive value.

Emphasis on reduction of pollution and water use will stimulate development of new food processing technology and recovery and utilization of waste products for feed and food uses. Energy consumption of the post harvest stages of the food system is more than double that used in agricultural production (113). There is potential for substantial savings through the development of energy-conserving processing and distribution technologies, and developing the use of solar and other energy sources. The high price of food, especially fruits and vegetables, will push research towards preventing losses during marketing. High prices will increase the dissatisfaction of consumers with products of poor edible quality.

There is a consumer demand for fresh as well as canned and frozen products. Nutritional labeling is already here for processed products and will be growing on a voluntary basis for fresh fruits and vegetables. Since some nutritionally important constituents are lost during distribution, especially under seasonally high temperatures, improved handling practices during marketing are becoming imperative.

Basic research on the underlying causes of post harvest deterioration in fruits and vegetables offers the possibilities of finding solutions to many problems. Chilling injury to susceptible fruits and vegetables, which include many important kinds, is an example. Is there a common cause of chilling injury that can be found at the cellular level?

Potentials in Development of Nonfood Agricultural Products

There is potential for increased efficiency and reduction in costs in the processing, marketing, and other aspects of post harvest technology of cotton and wool. Post harvest costs now comprise the major costs of fabrics and apparel made from natural fibers. For example, over 90% of the consumer's dollar spent for cotton denim dungarees represents post harvest costs (114). Many opportunities exist for development of more efficient handling and processing operations.

Agricultural raw materials are renewable resources for supplementing or replacing petrochemicals as industrial raw materials. Included are present agricultural commodities, feedlot residues, crop residues, and new untested crops. Currently, petroleum is the raw material for the production of some 228 billion pounds annually of synthetic organic chemicals that are transformed into countless useful and needed products and articles (115). Synthetic polymers (Plastics, rubber, fibers, etc.) alone use about one million barrels of oil, or oil equivalent in natural gas, each day to meet their yearly production of 50 billion pounds (116). Starch, tallow, and some vegetable oils are now competitive with petrochemicals as intermediates in the chemical industry and several billion pounds are now used annually for this purpose. Further opportunities exist for their utilization as has been demonstrated by recent innovative products based on research at the Regional Research Centers.

Past PHT research in cooperation with agronomists has laid a foundation for development of new crops as sources of industrial materials. Examples are kenaf fiber to replace newsprint (65% imported), guayule for natural rubber (100% imported), new oil crops suitable for growing in the United States to replace imported vegetable oils, and new plastics, coatings, lubricants, adhesives, pesticides, and other agricultural chemicals derived from plant constituents to replace petrochemicals. Many potential new crops combine fiber and food or feed nutrients with hydrocarbons, and processing the whole plant would be compatible with increased food, feed, and fiber production and possibly greatly improve agricultural productivity.

Potentials in Research in Market Exchange

Distribution of food over space and time is highly dependent on an efficient monetary exchange system. Direct marketing is physically efficient but reduces pricing efficiency. Prices, or more specifically the pricing mechanism, allocates productive resources among myriad activities and allocates food supplies among consumers over space and time. Consumer affluence depends on the efficiencies of specialization which in turn depends on the market exchange system. Inefficient pricing causes maladjustments in resource use and suboptimum allocation of products. Advancements in electronic and computer technology can be adapted to the market exchange system with adequate research and development. Electronic aids could also restore competitiveness to the food system thereby assuring that benefits of research and development would be passed on to consumers. Farmers would also benefit from competition in the marketing continuum and more accurate price signals.

Potentials in Research on Market Information

Efficient primary production, fabrication, preservation, and distribution of food depends on timely and accurate market information. Alleged shortages and surpluses are generally the result of inaccurate, untimely or misinterpreted market information. Food supplies are related to weather but the disruptions can be largely counteracted by appropriate storage strategies. Cycles in livestock production--caused by overreaction to market signals and biological lags--are particularly unsettling to both producers and consumers with alternating high and low prices. Moreover, cycles contribute to physical inefficiency. Over- and underproduction occur annually for most crops except tree fruits and nuts which are subject to longer cycles. More timely, accurate and appropriately interpreted market information could contribute to more stability in food supplies and prices and lower average costs due to improved physical efficiency, and also contribute to soil, water and energy conservation, labor efficiency and lower long run costs to consumers.

Potentials in Research on Transportation

An efficient and reliable transportation system is essential to the food system. In most cases, the ultimate consumer is far removed from the source of food. Water, rail and highway (truck) are the dominant modes of transportation in the food system. The more durable intermediate food and feed products are transported by rail and water-truck combinations. Highway (refrigerated truck) transportation dominates the movement of the more perishable foods. Distribution of perishable foods is most vulnerable to disruptions in the supply of liquid fuels and is also most vulnerable to domestic strife and alien attack. Research is needed to more efficiently utilize and maintain the transportation system. Maximization of back hauls or minimization of empty mileage, optimum location of processing and fabricating facilities are examples where research and development research can make the transportation system more cost effective. Computers and other electronic amenities can be adapted to the transportation system. Also, development of transportation systems less dependent on liquid fuels may be in order--one example is the potential for solar, wind, or biomass powered pipelines to move grain and oilseeds. A more efficient transportation system would contribute to energy conservation and particularly to a reduction in the use of liquid fuels.

Potentials in Research on Physical (Labor) Efficiency

The functions of warehousing, wholesaling, retailing, and food preparation and services are relatively labor intensive components of the ag-food sector. Improved labor efficiency in these functions offers perhaps the greatest potential for addressing the problem of relentlessly rising costs of foods to consumers. Also, appreciable time and energy (particularly liquid fuels) are consumed by the ultimate consumer in acquiring food, and the consumer is highly vulnerable to the disruption of supplies or the rationing of liquid fuels. Again there is a vast potential for using computers, video, and other electronic aids to reduce the labor (including the time of the final consumer) and energy requirements in warehousing, wholesaling, retailing, and food services.

Some Thoughts for Those Who Propose and Dispose

Selecting research objectives and determining the nature and size of research programs needed to achieve them are best determined by professional personnel and their administrators with appropriate input from competent advisors. These people, particularly the administrators and their closest staff advisors, should have the fullest possible grasp of the relative urgency of problems in the wide field of PHT research, and a keen sense of timing as to when shifts in program emphasis can be most productive from the viewpoint both of public need and research method. They should be sufficiently well informed and smart enough to recognize needs, articulate enough to make a convincing case for needed funds, and diligent enough to make sure that funds are efficiently spent so that Congress (for the public) has no problem in recognizing that there is real return for money spent.

It should be recognized that spectacular achievements in the conquest of space, culminating in the lunar landing in 1969, lulled many important people into believing that America's supremacy in science and technology would, of course, continue and that special attention could then be devoted instead to social goals. As a result, Federal investments in research and development and science education began to decline about a decade ago. While social goals are admirable and deserve to be pursued, neglecting to pursue the goal of excellence in science and technology can have dire consequences. Those who do PHT research in agriculture are among the important pursuers of this goal in the public sector. Their support should not be allowed to wane. To quote from a recent report of the National Science Foundation: "The economic well-being, security and health and safety of America during the remaining two decades of this century and beyond, will depend increasingly on our ability as a nation to strengthen our technological and scientific enterprise" (117).

Many realize that the remarkable achievements in PHT have sprung from research--research started soon enough and pursued hard enough by those thoroughly trained and equipped to do the job. It may not be fully realized how important "starting soon enough" can be. This is known as "lead time"--how long before you need the answer to a question do you need to start research to find the answer. Obtaining funds for research on those (to the uninitiated, "invisible") problems requires skilled salesmanship, yet in agriculture the need to have such funds is particularly great. With due respect for the difficulty of solving physical problems, they are invariably more quickly solved than the biological ones that predominate in agriculture. Physical problems succumb to research with fairly predictable regularity but biological problems are usually more stubborn. Some ninety chemical elements were discovered before the discovery of the first vitamin; airplanes and radio preceded the discovery of insulin by some twenty years; less than twenty years elapsed between the invention of the cyclotron and the explosion of the first atomic bomb but hybrid corn did not make its appearance until some seventy years after Gregor Mendel enunciated the laws of heredity. The agricultural research establishment with its background of skills and experience in things biological, should have the continuity of adequate resources it must have to arm us against future problems.

The Joint Council on Food and Agricultural Sciences, as well as the National Agricultural Research and Extension Users Advisory Board, established by the Food and Agriculture Act of 1977, helps administrators focus research on currently important problems. At the same time, caution must be exercised in following advice of such groups whose viewpoints, understandably, reflect biases. It is because they have strong viewpoints that they are members of such groups. Facts, where there are any, are hard to distill. However, since administrators now rarely have time to think about anything except the question immediately before them, it would also be most desirable to take a regular look at the long range scientific objectives and responsibilities of PHT research--a look from outside the forest where the horizon is not obscured by the trees. To some extent the above Council and Board provide such a look but their advice is bound to be more agricultural than scientific. It could be accomplished by re-establishment of the President's Scientific Advisory Committee which was ill-advisedly abandoned several years ago. Competent Committee members addressing the purely scientific aspects of agriculture's future problems would provide an additional and necessary safeguard to assure adequate foresight in approaching the future. This is particularly true with respect to areas in which basic research and exploration are needed. The level of funding for the more fundamental types of research is a function of what society can afford and in this respect is somewhat akin to the accumulation of capital in an economic system. A society that does not accumulate capital will soon begin to deteriorate and so it is with the accumulation of knowledge. In fact, knowledge is a part of the capital stock necessary to advancing productivity.

The sage who advised that the dishpan should be large enough to hold the dishes but not too large to fit in the sink, may have sounded a great truth. However, he obviously had had no experience with the Federal and State budgeting and appropriation processes or with the workings of the bureaucratic mind that must cope with them. There has long been a popular notion that an organization which is not getting bigger, is getting smaller. This seems to be characteristic whether one is talking about government research and development, universities, private companies, professional societies, or a host of other enterprises. Undeniably, the typical bureaucrat feels compelled to defend and expand his turf. Because of such recognized bureaucratic imperative toward self interest, however, it is often difficult for those who must "dispose" of budget requests to discern in Federal and State plans and estimates how much is self-serving and how much is essential in the public interest.

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APPENDIX

Additional Examples of Developments Resulting From PHT Research That Have Been Adopted Commercially to Improve Marketing Practices and Enhance Supply of Food and Kindred Products

1. The storage requirements of horticultural crops have been defined clearly in terms of temperatures, humidities, post harvest treatments, heat of respiration and storage peculiarities such as chilling injury. This information, which came from research conducted in the USDA, the SAES, and in laboratories in other countries is contained in Handbook 66 of the USDA. It is the standard reference for storage practices for fruits, vegetables, florist's and nursery stocks. Published first in 1933, it has been revised three times, the last one in 1968. This is a continuing effort to fill the gaps in knowledge and refine practices as new information is secured. Another revision is overdue (118).

2. Over the years, plant pathologists, specializing in post harvest diseases, have identified the common pathogens that attach horticultural crops. These have been described and illustrated by color photographs to provide a series of handbooks, organized by crops. Identification of the pathogens enable appropriate control measures to be applied. The market pathologists of the USDA have been responsible for getting together the information for publication, but the research work has come from many sources, the SAES as well as the USDA. This is an ongoing project requiring revision and updating the publications. In these studies there is close relationship between the post harvest pathologist and his colleagues in the field and orchard, where many of the diseases originate (119-127).

3. The research of the USDA on handling, transportation, and storage of perishables had a profound effect on the development of the modern refrigerator car. At the end of World War I, the refrigerator car fleet of the railroads was in poor condition and many were inferior in construction and performance. The private car companies, the railroads, and the U.S. Department of Agriculture formed a subcommittee, with equal representation, to draw up specifications for a standard refrigerator car, based on earlier studies of USDA. These investigations had shown that refrigerator cars needed more insulation and more space under the floor racks to improve air circulation and that basket-type ice-bunkers and insulated bulkheads would also improve performance (128). Again, after World War II, the railroads entered a rebuilding program for refrigerator cars. A Refrigerator Car Committee was formed by the United Fruit and Vegetable Association and a representative from the USDA served on the Committee. Recommendations for the new cars were drawn up based on many tests made by USDA researchers in cooperation with the car companies. Larger ice-bunkers, more insulation and fan-driven air circulation were some of the improvements adopted (129, 130, 131).

Icing of refrigerator cars became expensive as labor costs increased. Also, the frozen food industry had grown by leaps and bounds, and was now demanding zero degree (Fahrenheit) temperatures. About 10°F was as low a temperature as ice and salt mixtures could attain. The mechanically refrigerated trucks were giving the railroads tough competition (132). The railroads began to build new mechanically refrigerated cars and today they have completely replaced the ice-bunker car (133). Studies made by the USDA in the Western Utilization Laboratory on time-temperature tolerance of frozen foods had shown that at 0°F there was little loss in quality and nutritive value during usual storage periods (178). Food and Drug officials in several states joined in the effort to make 0°F standard practice for frozen foods. Efforts are continuing by the USDA to improve refrigerator cars and trucks, trailers and containers as well with the emphasis on saving energy and costs (87, 134-136).

4. Control of apple scald, once the most serious disease of apples in storage with the exception of blue mold rot, is now well controlled, thanks to research. Formerly it was not uncommon for susceptible varieties to become almost completely brown and worthless after removal from storage. The disease was not caused by a pathogen and is classed as a physiological disorder (137-139).

5. The freezing preservation of food has changed the eating habits of the American consumer. Early research of the USDA was on the breezing of berries in barrels for later processing into pies by bakeries, a practice reported in 1907 by Fulton (140). Many studies were made by the USDA and the SAES on selection of varieties of fruits and vegetables adapted to freezing, the blanching of vegetables, packaging, freezing rates, freezing methods, and freezing and storage temperatures, etc. (141-143). Frozen citrus concentrate was a new product, developed by the combined efforts of public and industrial research. It has made orange juice available the year round in a convenient form, and had increased the consumption of a product naturally rich in vitamin C (144, 145). Prepared frozen entrees and complete meals have helped the working housewife to prepare a quick dinner (146). What will be the next addition to frozen foods? Perhaps frozen milk concentrate, which could make significant changes in the dairy industry and add to consumer's convenience (147). More than 7.4 billion pounds of frozen fruits and vegetables, including potatoes, were produced in 1979 and about 200 million gallons of frozen fruit concentrate, mostly orange. Other major frozen foods were 2.6 billion pounds of poultry and 605 million pounds of seafood (148).

6. Maturity indexes for fruits, to determine when to harvest, have been developed by the USDA and the SAES (149-153). They have been incorporated into State regulations governing out-of-state

shipments and into Federal grades and standards. Examples are citrus fruits and avocados in Florida, pears in the Pacific Coast States and apples from the Pacific Northwest. The research has been beneficial in keeping immature fruit off the market and it has helped the consumer and producer as well.

7. Instrumentation research to develop rapid, nondestructive methods for determining the quality of food, has resulted in a number of devices that can detect defects in fruits and vegetables, measure internal color, sugar, fat and moisture content, and even the composition of grain in terms of protein content (154-158). This kind of research has helped in the grading of agricultural commodities and the payment to the producer in proportion to the quality of the commodity. The leader of this research, Mr. K.H. Norris, received the Alexander von Humboldt Foundation Award of $10,000 in 1978 for distinguished research contributions that led to a technology for simple and rapid measurements of the quality of food and feed grains.

8. Basic studies on the post harvest physiology of fruits and vegetables have been carried on in the USDA and the SAES laboratories. One of the notable accomplishments is the identification of ethylene as an endogenous product of the fruit or vegetable that acts like a hormone to initiate many ripening processes. The concentrations that bring about responses, the effect of temperature on the reaction, the origin of ethylene in the plant cell, and ethylene inhibitors have all been studied. The research offers an opportunity to find a method of preventing ripening and senescence in plant organs with the use of less refrigeration or none at all (159-163).

9. Recent advances in PHT research are summarized in the annual reports of 1979 and 1980 (164, 165). A few examples are given to illustrate the ongoing nature of the research, that one improvement in practice can well lead to many others. Ethylene acts as a ripening hormone and a stimulant of senescence in plants. An inhibitor of ethylene production in plant tissues has been sought as a means of slowing down or stopping its action. One has been found in the chemical aminoethoxyvinylglycine (AVG). When it was applied to fruit on the tree it delayed harvest and decreased post-blossom fruit drop. In other studies, it delayed the bloom of peaches and blueberries about 10 days, thus reducing the risk of spring frosts. Other applications will no doubt be found (166, 167).

Many investigators have found that peaches and nectarines have a short storage life of only 2-4 weeks under ideal storage conditions of 32°F. Internal breakdown and browning of the flesh occurs on longer storage. Researchers found that if storage at 32° was interrupted every 3 weeks by a warming period of 2 days at 65-68° and CA storage of 1% oxygen and 5% carbon dioxide was used, the storage life of these fruits could be lengthened to 6-9 weeks (85, 86).

Lowering the O_2 content of the atmosphere or increasing the CO_2 content extended the storage life of apples and many other fruits and vegetables. Recent studies have shown that the quality and nutritive value of peanuts can be preserved by low O_2 atmospheres without the need of refrigeration. There are also advantages in protection against insects and inhibition of molds and enzyme activity (168).

Post harvest diseases are responsible for losses in fruits and vegetables. Late blight of potatoes, caused by a fungus is a good example. It was responsible for the potato famine in Ireland in 1845 and 1846. Recent studies at the Wyndmoor, Pennsylvania, laboratory of ARS showed that the potato develops a fungistatic compound when infected with late blight (169, 170). Differences in potato cultivars in resistance to the fungus is related to the amount of the fungistatic compound they can produce.

There are many fruits and vegetables that cannot be held at 32°F with its advantages in retarding ripening and development of decay. They develop chilling injury as evidenced by browning of the flesh and skin, sunken areas or pits on the surface, off-flavors, and decay. Chilling injury of bananas is a common example, but it occurs on citrus and other subtropical fruits and vegetables. Recent research has shown that if cucumbers and sweet peppers are dipped in sodium benzoate or ethoxyquin, chilling injury was reduced. Intermittent warming for 24 hours at 3-day intervals during cold storage also alleviated chilling symptoms. These findings could lead to commercial methods of extending storage life by chilling sensitive vegetables (171).

10. Essences and full-flavor fruit juice concentrates. USDA scientists developed the first practical process by which the appealing characteristic fresh aroma of a fruit juice, normally lost during processing, can be captured in the form of a concentrated, highly potent liquid "essence" (172-176). The process reduces the rest of the juice to a syrup having one-fourth to one-seventh of the original weight and volume, to enable economical storage and shipping from producing areas to consumer. The essence may be used separately or added back to the juice concentrate to restore the flavor and aroma of the fresh product. These products are also used commercially in preparing a variety of foods such as jellies, table syrups, blended fruit drinks, candies, and frozen desserts. Commercialized in 1950, over one-hundred commercial essence recovery units have been placed in operation. Estimated cumulative sales are more than $1 billion (177)

11. Time-temperature tolerances of frozen fruits, vegetables, and quality maintenance. Factors of quality, storage temperatures, and holding time were related to reliable quantitative terms in frozen

foods in classic time-temperature-tolerance investigations conducted by USDA scientists (178). Sound limits were developed on the times and temperatures that frozen foods could experience during their commercial lives while still maintaining high quality. In a cooperative effort, the frozen food industry used the information obtained to establish a recommended code of handling practices (179). The continued rapid growth of the frozen food industry, now supplies nearly 97 lb food per capita annually, has been, in part, dependent upon consumer satisfaction resulting from application of findings of this research as they have led to improved industry practice and improved product stability (180).

12. Potato flakes--a new convenience food. The process for making potato flakes, a new form of dehydrated mashed potatoes, was developed by USDA scientists (181, 182). Flakes rehydrate instantly in hot or cold liquid to produce mashed potatoes similar to the fresh counterpart. Seventy-five percent of the vitamin C in potatoes, their most important vitamin, is retained in the reconstituted mash--often more than is present in fresh potatoes after storage (183). Flakes are now made in 13 plants located in all major potato producing areas of the U.S., and are widely distributed in supermarkets, known to the consumer as "instant" mashed potatoes (184). Plants have been built in at least 10 foreign countries, many by American contractors, and others are currently being constructed. Potato flakes also serve as the starting material for frozen french fries and another processed food product, preformed potato chips, which were introduced into the market a few years ago. From 1958 to 1978, about 4.7 billion pounds of dehydrated potatoes were produced (185). Estimated cumulative net value added exceeds $500 million (186). The Eastern Regional Research Center, USDA, received the first Food Technology Industrial Achievement Award of the Institute of Food Technologists in 1959 for the development and commercialization of a process for producing instant potato flakes (184). The invention was one of two for which the 1980 Isker Award was given by the Research and Development Associates for Military Food and Packaging Systems, Inc. (187).

13. Soybeans for oriental foods. Japan is the largest single foreign consumer of U.S. soybeans. The Japanese, who use the whole bean in their traditional foods, objected to certain characteristics of the U.S. soybeans such as uneven cooking, dark-colored products, and undesirable flavors. USDA research, in cooperation with Japanese scientists, has overcome these objections through improved processing techniques and evaluation procedures, and identification of the most suitable U.S. soybean varieties for use in soybean foods (188-190). The improved processes developed by USDA for several oriental soybean foods, including tofu, tempeh, and miso, have been the basis for a new food industry which has developed in the U.S. since 1975 (191-194). Over 200 companies with annual sales of $45 million are now reported to be producing these soybean food products (195).

14. Xanthan gum--a new stabilizing ingredient for processed foods. In the search for a substitute for plasma as a blood volume expander for use by the military in the Korean war, USDA scientists discovered a particular bacterial strain that produced, economically and efficiently, the starch-like carbohydrate dextran (196-199). This was the most satisfactory dextran ever tested clinically and was widely used in the Korean war. Following the dextran development, USDA researchers undertook a systematic study of the composition, structure, and properties of polysaccharides elaborated by a large number of microorganisms grown on corn sugar as a substrate. The unusual properties of one of these polysaccharides--high viscosity at very low concentrations, and little effect on viscosity of changes in temperature, acidity, or salt concentration--recommended it for a variety of food and industrial operations, the latter including oil-well drilling and secondary recovery operations (200, 201). In many of its food uses, xanthan gum replaces imported vegetable gums. Three plants for its manufacture have been built in this country, two for food-grade xanthan gum (202) and one for products for the oil-well industry. Two plants have been built overseas in joint ventures of U.S. and foreign firms (203). Capital investment by U.S. companies is estimated to exceed $100 million. Production capacity is estimated to exceed 40 million pounds per year (201). The Northern Regional Research Center, USDA, received the Food Technology Industrial Achievement Award in 1977 for its discovery and contributions to the development of xanthan gum as a commercial food ingredient (204).

15. Dry caustic peeling process for fruits and vegetables reduces pollution and water usage. In this process, the fruits and vegetables are held in a hot lye solution for a short time to allow penetration of the lye below the skin layer, then dry-scrubbed to remove almost all the skin in a semi-solid form, and given a minimum wash with water sprays (205-207). Benefits include reduction in volume of effluent and quantity of organic load (pollution), reduction in usage of water, increase in product yield and by-product recovery, and increase in quality of the peeled product. The process is being used to peel white potatoes in more than 65 plants in the U.S., and is almost standard in the tomato canning industry. It is also being used commercially to peel several other commodities, including sweet potatoes, beets, carrots, peaches, apples, and pears. The development was awarded "Top Honors" in the category of food processing innovations by Food Processing magazine (Putman Publishing Company) in 1971 and was also awarded the 1972 Industrial Achievement Award by the Institute of Food Technologists (208). Estimated annual savings based on increased product yield and by-product recovery (2 and 20%, respectively, for potatoes) is about $15 million. This estimate does not include savings in waste treatment and environmental impacts (209).

16. Formulated foods for the Food for Peace program. USDA research has made major contributions to the development of high-protein formulated foods that have been donated by the U.S. to developing countries under the Food for Peace program. PL-480

gave USDA the responsibility for purchase of these foods. Guidelines for nutrient composition were developed by USDA, in cooperation with the Agency for International Development (AID) and the National Institutes of Health (210). Issuance of these guidelines generated cooperative efforts between USDA, trade groups, and private industry on the development of prototype products. This work resulted in the development of formulated foods for diet improvements in maternal-child feeding, school feeding, food for work projects, and disaster relief. Foods developed in the period 1965-1974 included corn-soy-milk (CSM), instant CSM, wheat-soy blend, wheat-soy beverage, and whey-soy beverage, intended primarily as child food supplements; and soy fortified bulgur, bread wheat flour, cornmeal, sorghum, grits, and rolled oats as supplements for older age groups. USDA scientists conducted extensive processing, packaging, storage, analytical and organoleptic tests on these products as a part of the development of specifications for all purchases (211-214). Up to one billion pounds per year of these processed food products have been shipped overseas since 1965 providing relatively inexpensive, but highly nutritious, selection of food supplements that have been acceptable in countries with diverse food habits (215).

17. USDA research assists maple syrup producers. USDA research has resulted in higher yields of better sap, boiled more efficiently to high quality syrup at less cost to the producer-processor and provided him more income from this off-season activity. The increased holding time of sap resulting from better sanitation has allowed separation of sap collection and processing, creating a new income source, "sap farming". Major improvements that have brought this about are the sanitizing taphole pellets, improved layout and sanitizing of plastic sap collection tubing, ultraviolet treatment of sap for preservation, promoting the central evaporator concept, better design for evaporators, steam-removal evaporator hoods, and automatic instrumentation for boiling and finishing (216). New and improved products developed by USDA scientists include high-flavor syrups, maple fluff, better crystal-coated candies, and free-flowing maple sugar (216-223). Early USDA findings were commercialized in 1952. This maple research has added an estimated $48 million to the rural economy of the eleven maple-producing states since 1952 (224).

18. Commercial development of penicillin. The production of penicillin, based on the earlier discoveries of Alexander Fleming was very inefficient and laborious process, and was not readily adaptable to large-scale operations. Work by USDA scientists resulted in a deep-tank process, similar to those used in the distilled liquor industry, wherein the producing mold, a penicillium, could be grown and readily produce penicillin in large amounts. Factors leading to this success were the discovery that milk sugar and corn steep liquor (a by-product of the wet corn milling industry) in the fermentation medium increased penicillin yield, and finding higher yield strains of the penicillium (225-227). Industry was immediately furnished these discoveries and, as a result, penicillin became available to th

Armed Forces during World War II. This work led to the current antibiotics industry which now produces literally scores of antibiotics for the treatment of disease. Cumulative value of the penicillin alone produced totals over \$1.2 billion (228). In recognition of the contributions of the Northern Regional Research Laboratory, USDA, the American Institute of the History of Pharmacy and the Illinois Pharmacists Association dedicated, in September 1980, a bronze plaque at the Northern Laboratory "in honor of those who shared in the discovery and development of penicillin during World War II". This is only the tenth such award in the Institute's history of 100 years.

19. Processes for production of vitamins B_2 and B_{12}. Vitamins B_2 and B_{12} are extensively used in fortifying feeds for poultry and small animals and in the preparation of pharmaceuticals. USDA scientists isolated high-yielding organisms and developed fermentation processes for production of these vitamins (229-232). Cumulative values of the vitamins produced by these processes is estimated to exceed \$75 million (233).

20. Superior stabilizers for plastics from fats and oils. From basic studies on the reactions of unsaturated vegetable oils with organic peroxides and the properties of the resultant "epoxidized" oils, USDA chemists developed products that keep plastics from becoming brittle with age (234, 235). These modified oils blend well with commercial plastics, do not evaporate, and lessen the need for the addition of metal salts which make the plastics cloudy. The epoxidized oils are particularly valuable in chlorine-containing plastics, where they minimize cracking and discoloring caused by heat and sunlight. About 120 million pounts a year of the epoxidized oils are used currently (236). The estimated cumulative net value added by this development is \$176 million (237).

21. Major market developed by tallow and grease in feeds. USDA research demonstrated that blending industrial grade tallow and grease at levels up to 10% into mixed feeds offers a number of advantages (238-240). Fat provides a high energy component, results in improved preservation of carotene and vitamin A, improves appearance and palatability of the product, and eliminates dustiness during handling of feed meals. Well over a billion pounds of tallow and grease are now used annually in feed formulations, providing a market for about 40% of the industrial grade tallow and grease produced in the United States (241-243). It is estimated that this cumulative net value added as a result of this development is about \$160 million and that more than 20 billion pounds of animal fats have been used in this development (244).

22. Improved leather from hides and sheepskins. USDA scientists discovered that the chemical glutaraldehyde combines chemically with the proteins of hides and sheepskins to give unusually stable tannage (245-248). The USDA-developed process for using glutaraldehyde is now in commercial application by about 30 tanners in the

U.S. The process is versatile, rapid, and efficient and the resultant mellow leather is receptive to oils, dyes, and finishes. It is being applied in the production of leather used in shoe uppers, shoe linings, work shoes, and jungle boots for the Armed Forces. The glutaraldehyde tannages is now applied in 10% of the leather production. According to industry sources net value added due to improved properties is about 5 cents per square foot. Estimated cumulative net value added by the development is about $36 million (249). This does not include the value of the development applied to the sheepskin shearling industry. The American Leather Chemists Association presented Dr. E.M. Filachione the ALSOP award for his contributions to the discovery and development of glutaraldehyde as a tanning agent (250), and the French Leather Association presented him the Association's 1978 Gold Medal for this research (251).

23. Cotton textile mill machinery. Cutting manufacturing costs of cotton textiles while maintaining or improving product quality are necessary requirements for holding a place in a competitive market (252). Mill operators believe that machines invented by USDA engineers will do this, as shown by their purchases of these machines. Every high-production card manufactured today (20,000 are now in use) is equipped with the Fiber Retriever, a device that removes more trash and short fibers from cotton while reducing the loss of spinnable fibers (253). Some 300 Opener-cleaners are in use in the U.S., with capacity to process a third of all cotton consumed in this country (254). The Opener-cleaner supersedes the Opener, also a USDA invention, of which about 150 were installed in U.S. mills. The Granular card, also developed by USDA, is the first innovation in carding principles in 200 years (255). About 10,000 of these machines are installed, about 20% of the total in the U.S. An inexpensive attachment for looms makes it possible to weave cotton fabric so dense that it is wind- and water-proof without chemical treatment. Every major piece of mill equipment developed by USDA is commercially available. Estimated cumulative value of research calculated as net manufacturer's value added, $60 million (256).

24. Processing techniques for cotton mills. Many USDA-developed improvements in processing techniques for cotton textile mills have been adopted by commercial operators, to their advantage and the advantage of the cotton industry and the consumer alike. Studies of mill operations established guidelines which enable mill operators to adjust machines for operations at maximum speeds consistent with efficiency and product quality. Cotton fibers, a natural product, vary greatly in length, fineness, and maturity. USDA technologists determined blends and processing procedures for cotton of differing fiber properties, so that spindle speeds have been increased 20% without loss of efficiency, supplying guidelines adopted widely by industry. These investigators developed previously unknown information about fiber orientation and fiber hooks. Manufacturers are now making instruments to measure these two factors. They report that textile manufacturers are using them to improve mill operations. Estimated cumulative net manufacturer's value added, $400 million (257-261).

25. Flame-retardant finish for cotton. Up until the late 1960's, there was no flame-retardant finish available for use on lightweight cotton fabric which did not cause undesirable increases in fabric stiffness and/or excessive losses in fabric strength. USDA scientists discovered a unique process for imparting flame-resistance to lightweight cottons as well as the heavier weight cottons (262-265). This process was based on a chemical rather than a heat-cure process, involved the use of THPOH and ammonia as the chemical curing agent, and was hence called the THPOH-NH_3 cure process. In 1971, Southern Regional Research Center entered into a Cooperative Agreement with United Merchants and Manufacturing Co., Inc., Langley, S.C., and Cotton Incorporated, Raleigh, N.C., to more fully commercialize this treatment. It quickly became the most widely used flame retardant for cotton textiles, both woven and knitted goods, in the industry. The key advantages of cotton finished with the THPOH-NH_3 finish is durability to repeated launderings, finished fabric is soft and pliable, fabric strength is not adversely affected, when exposed to a flame it forms an insulating char, the finished fabric is odorless and it absorbs moisture even better than unfinished cottons and is hence quite comfortable when worn next to the skin. Today, this finish is being commercially applied to all types of cotton fabric by commercial finishers. Fabrics so treated are finding use by municipal fire departments, foundry workers, automobile manufacturers, the military, and, most recently, in the space shuttle as well as other NASA applications (266).

26. Insoluble starch xanthate (ISX) for pollution control. Investigations by USDA scientists on the chemical and physical properties of starch xanthates formed by the reaction of starch with sulfides revealed their capability for sequestering heavy metal ions present in solutions at very low concentrations (267). The product is uniquely effective in removing traces of heavy metal contaminants from effluent industrial process water (268, 269). The final stages of research on this product received support from the Inorganic Chemicals Branch, Industrial Environmental Research Laboratory, EPA. The Chief of this Branch called it "...one of the best and most productive research efforts sponsored [by his branch]." At least 10 metal plating firms have installed the ISX treatment to meet EPA requirements. Nine companies have licensed the USDA ISX patent, and three are currently supplying the product (270). The Northern Regional Research Center was presented the I·R-100 award by Industrial Research/Development magazine for the development of insoluble starch xanthate as one of the 100 most significant new technical products in 1978 (271) and also was awarded the 1978 1st Place Product Advancement award by Pollution Engineering magazine for "Significant product development advancing the state of the art in design and installation of a cost effective, energy conserving system to control water pollution" (272).

27. Super Slurper, a new starch derivative with diverse applications. USDA scientists pioneered the study of the chemistry of the graft polymerization of synthetic chemicals onto starch to form new molecules, some with unusual properties. One of these,

known as Super Slurper, because of its capacity to absorb 300-500 times it weight of water, received the Industrial Research magazine I•R-100 award in 1975 given for the most significant new products developed during the past year (273) and the Inventor of the Year award given by the Association for the Advancement of Invention and Innovation in 1977 (274). Fifty companies have licensed the USDA patent and four commercial firms are already manufacturing products based on this invention (275). These companies are engaged in market development in a wide range of agricultural applications (e.g., seed coating to improve germination and stand, root coating of bare wood nursery stock and vegetable transplants) and consumer uses (e.g., personal care products, burn and wound applications in human and veterinary medicine). Each firm makes its own particular version of the USDA prototype to achieve some proprietary advantage and capitalize on extant processing and marketing strengths. Independent estimates have placed the total market potential for Super Slurper-like products at about one billion pounds annually (276).

28. Fungal amylase for production of ethyl alcohol. The starch in cereal grains must be converted to fermentable sugars before it can be utilized by yeast in the production of ethyl alcohol. Traditionally, malt has been used to carry out this conversion. However, malt is a relatively expensive raw material and is at times in short supply. A survey of fungi from the USDA Culture Collection indicated that several showed promise as converting agents for the saccharification of starches. An amylase process was developed for the production of converting agents from microorganisms and their utilization in alcohol production (277). Contract studies made in an existing alcohol plant enabled commercial costs to be determined. The tests showed that a saving of 2.7 to 3.9 cents per gallon in the overall production of alcohol could be realized with fungal amylase as compared to malt, under the relative prices for malt and grain (278). Importance of enzymes for this use is evidenced by the recent announcement of construction of a $20 million plant for production of enzyme for use in fuel ethyl alcohol manufacture (279). At the projected production rate of 500 million gallons of fuel alcohol per year from grain by the end of 1981, the use of enzyme represents an annual savings of up to $20 million (280).

29. ProXan, a-protein-xanthophyll concentrate separated from alfalfa. On a per acre basis, alfalfa is one of the highest yielding protein crops grown in the U.S. It is also rich in xanthophyll, a pigment desired in egg and broiler production. Studies of USDA researchers showed the technical feasibility of removing a protein-xanthophyll concentrate from juice mechanically expressed from green alfalfa as the first step in the dehydration of alfalfa by commercial dehydrators (281-284). In addition to the recovery of a valuable feed component, mechanical removal of part of the moisture from alfalfa reduces energy consumption (285). The process has been developed as a commercial scale operation overseas (286), and is now under commercial development in the U.S. (287).

30. Process for separating gluten proteins from wheat flours. USDA investigators developed a method for separating gluten proteins from wheat flour that required less processing waters than conventional processes and lowered the cost of recovery of water solubles (288-290). A commercial process based on this research has been developed and operated in Europe and a plant recently installed by a European equipment manufacturer is now operating in the U.S. (291, 292).

31. Advance in methodology for measuring flavor quality of food products. Unconventional and unique gas chromatographic techniques that rapidly and effectively measure the flavor and keeping quality of raw and processed food products are being developed by USDA scientists (293, 294). Since the instrument-collected data of certain foods correlates so well with taste panel flavor scores, both industry and academia have welcomed this breakthrough as a practical, objective technique for appraising food flavor/quality. Several major food industries have adopted this unique method for measuring the flavor quality of salad and cooking oils, butterfat, mayonnaise, peanut butter, and rice breakfast foods. Other successes experienced in various other food laboratories have resulted in increased efforts to broaden its uses. This unconventional method may be used to substantially decrease costs and shorten the development time for new and acceptable food plant varieties by providing an objective method to evaluate flavor quality at early stages of breeding when only a small amount of plant material is available. Agronomists and agricultural engineers foresee potential for this technique in assessing the effects of agricultural practices on flavor quality. Food processors also recognize the inherent possibilities of this technique for monitoring incoming raw materials and production lines and modifying their manufacturing methods to provide higher quality products with extended shelf life, at a reasonable cost to the consumer. Licenses to practice the patent have been issued to many companies, and the equipment is being built and sold by an instrument manufacturer.

32. Development of least cost routings for the transportation of products to market. The problem of transporting goods to market as efficiently and inexpensively as possible has been with man since he evolved from the subsistence-type economy and became dependent upon others for food and fiber. The number of customers and the size of service areas covered by many assembly or distribution systems make it practically impossible for even the most experienced route manager to evaluate all routing alternatives. Computerized quantitative methods are available to aid in the development of efficient least cost routing networks. Experience with these procedures has been beneficial to firms who have chosen to evaluate their transportation systems. For example, an analysis of the delivery network for an Alabama wholesale milk distributor indicated that through the development of more efficient routes, total delivery costs could be reduced 16% (295). Also, total time required to make delivery was lowered by 35%. Such savings are significant and are important in considering ways to reduce or limit future food price increases.

33. Flexible adhesives and coatings from fats and oils. USDA chemists in basic studies investigated properties, reactions, and polymerization of "dimer" and "trimer" acids formed from unsaturated fatty acids from tall oil or acidulated soybean soapstock (296, 297). The dimer acids, now consumed in the amount of 40 million pounds annually, have major applications as polyamides in hot melt adhesives for shoe soles and book bindings, flexographic printing inks, epoxy adhesives and epoxy coatings (298). Lesser applications such as lubricants and corrosion inhibitors are growing markets. Current price for dimer acids is about $1.25 per pound, and the net value added by this development is estimated at $0.50 per pound for a cumulative total of $373 million (299).

34. Research applications that have resulted in citrus as a major industry. Along with the development of frozen concentrated juices, research was done on utilization of the non-juice portions of citrus fruit, which amounts of 45% of the entire fruit currently amounting to approximately 4 million tons (300-302). As a benefit of this SAES and USDA research, there has been developed a large and stable by-products industry utilizing virtually 100% of the waste materials from the juice extraction process. This also has increased the value of the crop, improving the economy and virtually resolving a potentially large waste and pollution problem.

For many years, the production of lemons in Florida was limited to dooryards and very small scale fresh fruit operations for local markets and some gift box trade. Through SAES and USDA research, methods were developed to handle Florida-grown lemons so that now there is a multimillion box production of lemons, worth many millions of dollars (303-306).

With the advent of pulp wash concentrate for the beverage industry, the citrus processing industry was faced with a dilemma as to how to best produce a high density concentrate due to an aggravating viscosity problem which limited concentration to no more than 25 to 40 degrees Brix. SAES enzyme research demonstrated that pectic enzymes could be used to reduce viscosity with no deterimental effect on concentrate quality and today 60 to 65% Brix pulp wash concentrates are produced routinely (307, 308). This process has led to energy savings, lower shipping costs, reduced warehousing requirements and other improvements in efficiency as well as reduced costs.

SAES research has demonstrated that citrus juice sacs are a major contributor to air pollutants from citrus feed mill stack gases. The segregation and recovery of juice sac which may be dried and utilized in human foods has resulted in substantial economic returns to the citrus processing industry with accompanying reduced pollution (309).

35. Development of processed foods from whole soybeans. SAES research has developed a number of foods from whole soybeans. It has been apparent that there is a worldwide need for additional protein for human consumption, and soybeans have protein content of excellent nutritional quality. A controlled heat treatment for soybeans was developed to eliminate objectionable flavor development before damage to the whole bean occurred during processing. A series of prototype foods including such items as weaning food, canned bean and meat mixtures, breads, and a number of dairy-like analogs have been developed (310-313). There has resulted a considerable interest in this particular process and several companies (both domestic and foreign) are investigating its marketability. This particular post harvest research result has strong implications in the international arena and is being further developed through the auspices of several international programs. The adoption of this technology will result in energy savings and considerable economic advantages for equivalent nutrition when compared to alternate protein sources. Its impact on the economics of soybean production would be apparent following wide-scale use of this food product line.

36. Sterile fluid milk. The concept of sterile milk is not new, but it has not been accepted by the American consumer because of a "cooked" flavor. SAES scientists, working with a thin film sterilization technique developed by DASI Industries, have produced a sterile fluid milk product that is as acceptable as normal pasteurized milk (314-316). The introduction and utilization of this product has the potential for significant energy savings and improved quality, and should result in lower costs to consumers (317). The first year of a 3-year study sponsored by the Department of Energy to develop a pilot plant and to conduct market studies is currently underway.

37. Modification of storage procedures to control disease in the Centennial sweetpotato variety. A disorder of the leading sweetpotato variety, Centennial, began to appear several years ago, noticeable only after the potatoes were cooked. Because sweetpotatoes with this disease showed no external signs, the losses from this disorder were borne completely by the consumer and/or the retailer. In one year alone, losses due to this disorder were estimated to be 1 million pounds in the New York Metropolitan area. Plant pathologists participating in a specific Cooperative Agreement between the New Jersey Agricultural Experiment Station and ARS discovered the cause of the disorder and developed a simple, specific storage regime which eliminated it. Not only did these studies "salvage" the Centennial variety but were responsible for the introduction of the hard core resistant, Jewel variety (318).

38. Country-style ham developed into a major industry. In country-style ham studies, the interrelationships of curing times, equilization of curing ingredients within hams, aging time, and control of relative humidity, temperature, and air flow were determined. This work resulted in controlled moisture losses, more rapid flavor development, elimination of mold growth and more complete stand-

ardization of ham quality. The country-style ham industry developed rapidly in North Carolina after it placed into practice the results of this SAES research. The gross income of the industry grew from about $10 million per year to about $100 million in about 10 to 12 years (319).

39. Quality processed potato products depend upon proper handling and storage techniques of the raw material. The bulk of these are processed into flakes, chips, and frozen products such as fries. This requires long-term storage of much of the crop before it can be processed. Researchers have shown the importance of proper handling and storage techniques to prevent bruising and excess sugar buildup, that results in inferior potato chips and french fries, which are major products (320-324). The benefits from the development and implementation of new potato storage technology were estimated by SAES researchers. The value of future benefits over the 27-year anticipated life (1974-2000) of this technology was estimated at $3.4 billion (325). The implementation of the new storage method has directly or indirectly contributed to a 543 person per year increase in employment in the processing sector of the Idaho potato industry. This increase in employment in one of the major potato growing states has contributed a $3.3 million annual increase in wages (325).

40. Mechanically deboned meat provides consumers a high quality food at a low price. SAES research on mechanically deboned meat has dealt with the composition, safety, and nutritional value of meat which in the past has been wasted because it could not be economically removed from the bone (326, 327). Mechanical deboning makes it possible to obtain 15 pounds of additional meat from each beef animal, 5 pounds of additional meat from each hog, and 3 pounds of additional meat from lamb or mutton (328). In addition to the increased volume of meat, more efficient use of labor should allow the packer to pay the producers more for livestock. The mechanically deboned meat is being exported to other countries, expanding the market for livestock products.

41. Hot-boning beef. Research at several SAES has demonstrated significant potential advantages of "hot-boning" beef carcasses (after 2 hours of cooling) compared to the traditional 48 hours of cooling. Reductions in refrigeration input and also cooler space of 42 to 47%, respectively, have been attained. Labor time can be cut by 25% for a 480-head per day slaughter-processing facility. This process, presently being adopted by the industry, facilitates centralized processing, while significantly reducing fixed capital and inventory cost. Carcass shrink (due to time in coolers) was cut in-half which alone could save $6 per head at today's prices. Microbial counts, cutting yield, shelf life, cooking shrinkage, drip loss, water binding capacity, and acceptability of hot-boned beef were found to be equivalent to the more traditional procedures. Problems exist in grading carcasses 2 hours post-slaughter vs. the traditional 48 hours post-slaughter and in preventing cold-shortening of muscle fibers (toughness) by not chilling below 10°C (50°F) within the first 10 hours post-slaughter. SAES scientists are investigating alternate methods of grading and product management to overcome these recognized disadvantages (329-332).

42. Lowering pollution. Broiler processing plants use large quantities of water and the disposal of the waste water is a costly part of doing business. SAES research has characterized the quality of water at different positions in the processing plant and by relocating screens and pumps has upgraded waste quality. Water is used to wash carcasses during the eviscerating process and fragments of skin, fat, and connective tissue accumulate in the wash water. This work demonstrated that placement of screens ahead of the pumps permitted removal of these bits of tissue. Screening after the water passed through the pumps was much less effective because the pumps broke up the particles. The work further demonstrated that screening should occur in positions within the plant where water contains the greatest concentration of meat particles rather than at the end of a line where dilute and concentrated streams have become mixed. When these principles were applied to one processing plant which killed 50,000 birds per day, the cost of sewage disposal was reduced by $3,500 per month. When applied on a national basis, this would result in savings in excess of $10 million annually (333, 334).

43. Sectioned and formed meats. Sectioned and formed meats are particles of meat bound together to produce portions of the size and shape desired. There are several advantages for applying this technology according to SAES scientists. Livestock producers are able to receive increased benefits since it is possible to use portions of the animal carcass that are low in fat and connective tissue. The portions can be combined through appropriate technology to produce roasts and steaks. This gives increased value to livestock produced and more efficient utilization of protein available. Approximately 20% of the hams produced under Federal inspection are of a sectioned and formed nature. A number of beef roasts and steak-like products are being produced commercially today. A processor combines low-fat and -collagen meat by subjecting it to particle size reduction, the action of salt and phosphate, and mechanical agitation. These treatments when applied by appropriate equipment, result in tender chunks of meat that will bind together. This permits a processor to produce portions of the size and composition that the consumer demands. The consumer is very interested in obtaining food material in the exact portion and composition that is appropriate for the household that is doing the purchasing. With sectioned and formed meats, the consumer can be supplied with nutritional information as to the composition of the product. There is no waste and the consumer receives additional benefits due to being able to buy meat in the exact quantities desired. Additional areas that would benefit from research include: Decreasing the level of salt and phosphate used in the process; increasing the yield of functional proteins from livestock and poultry; increasing the effective removal of collagenous protein from meat tissue without destroying its structure and decreasing equipment cost and increasing production efficiency in the manufacture of sectioned and formed meat products (335-338).

ISSUES AND OPTIONS

ISSUE 1: Are the current roles of the participants in PHT research in the United States well-defined and appropriate?

Findings

---The participants are the USDA (principally ARS, CSRS, and ERS), the SAES, and private institutions.

---Generally, USDA is expected to exercise leadership in assuring that problems of current and future significance to agriculture in the United States are addressed; the SAES emphasize problems of concern to the state or of the region of which they are part; private industry engages primarily in product and process development with emphasis on short-run profit potential.

---USDA is the only participant with authority that carries responsibility for addressing PHT problems having national impact.

---In the process, USDA must always conduct research on local, state, and regional problems and the research of SAES and private industry, whose primary purposes are more limited, usually contributes to solution of national problems.

---While these roles of the performers have historic precedent and are still appropriate, they are not clearly defined.

---USDA, with the cooperation of the SAES, has the "machinery" to coordinate Federal and State research in PHT.

---Competition among State and Federal performers expedites the solution of problems confronting the post harvest sector--there are no second place prizes in the professional community. Competition is a powerful motivating force undergirding the food sector.

Option 1: Maintain present roles with clarification. This option would imply continuation of most procedures already in effect, that is:

---USDA would continue its role as lead agency in the Federal Government and would continue to coordinate all PHT research conducted or financed by Federal funds.

---Federal funds allocated to ARS and ERS for PHT research would be devoted primarily to problems of national importance where the nature and/or magnitude of the problem is such that a single state could not be expected to provide adequate resources or where the risk is too high to make the work attractive to private industry.

---ARS and ERS would continue responsibility for servicing the research needs of the action and regulatory agencies of USDA.

---ARS and ERS would remain responsible and accountable to both the executive and legislative branches of government for the administration and national coordination of such programs.

---ARS and ERS would continue to have responsibility for initiating research programs directed toward problems of national import.

---Federal funds allocated to CSRS would be used, particularly through formula grants, by SAES for PHT research on local, state, and regional problems, and on national and/or international problems that are extensions of their state and regional efforts; CSRS would continue to exercise limited control over programs conducted by SAES, but would provide monitoring and review services needed for coordination among State and Federal performers.

---Where USDA and SAES are both involved in aspects of regional or national problems, research programs would be developed cooperatively.

---SAES and other institutions such as non-Land Grant universities would compete for non-formula grant funds on the basis of their ability to perform needed research effectively.

---The 1890 Land Grant institutions would continue to receive Federal funds and carry out their present role with improved coordination with other programs supported by Federal funds.

---The private sector would continue without additional incentives or other inducements to conduct the research that best fits the interests of the individual firm.

PROS

---This option provides the Congress and Executive branch one Federal agency, USDA, to hold responsible and accountable for a system of coordinating all Federal PHT research funds, and responsible for broad regional, national, and international research programs in PHT.

---It provides a mechanism (when properly organized and managed) to carry out programs of immediate concern to the Congress and/or the Executive Branch, and respond quickly to their mandates.

---It provides a mechanism whereby Federal funds can go directly, through formula funding, to the SAES and 1890 Land Grant institutions to maintain their research base so that their extensive resources can be utilized cooperatively on problems of national concern.

---It provides a means through grant and contract funding to enlist the aid of other interested research institutions in meeting the goals of PHT in the United States.

---It assures continuation of a system whereby the nature of the research performed under formula grants in the SAES is determined primarily by the SAES themselves, without Federal directives but with Federal assistance in monitoring and coordination.

---It provides means, through USDA's coordination responsibility, to avoid unnecessary duplication of PHT research effort.

---Private industry would continue its PHT research and development in accordance with the free enterprise system with continuing encouragement from USDA and SAES to address those problems the solution of which would result in most benefit to the public.

CONS

---This option provides too little direction and centralized control over use of Federal funds for PHT research.

---SAES have too much latitude in using Federal formula PHT research funds and should be required to jointly plan with USDA.

---Because of lack of strong centralized control, some problems receive insufficient attention, some more than sufficient attention, and some adequate but not timely attention.

---CSRS now operates more as though it were under supervision of SAES directors than under USDA.

---The administration of both formula and other grants by CSRS can tend to favor the SAES over non-state institutions.

Option 2: Eliminate the in-house role of USDA and utilize the freed resources to increase funding to the SAES to enable them to conduct most publicly-supported PHT research.

PROS

---A non-existent bureaucracy cannot grow in numbers or influence.

---SAES have facilities (and would likely have for use the present Federal facilities in the states) and staff competence to conduct PHT research now being done in-house by USDA.

---SAES directors and researchers would have more freedom to conduct research they deem necessary and desirable without Federal constraints.

---There would be no need to coordinate State with non-existant Federal programs.

---Funding could be accomplished through the existing machinery of CSRS.

CONS

---The Congress and the Executive Branch would be deprived of a PHT research facility and staff "readiness", that is, of a directable and readily available research arm where conducting desired PHT research could be mandated, making it necessary to request SAES to do such research.

---While this option provides for accountability, it provides no mechanism, agency, or individual to be responsible for the identification of specific research needs or that specific needed programs will actually be carried out.

---National programs are not efficiently solved by large numbers of individuals working separately as they would be in the several states, but by a few (as is now the case in the Federal in-house programs) concentrating their efforts on the critical aspects of the problem and coordinating the work with that of others wherever it is being done.

---Requiring the states to assume responsibility for research on PHT problems of national import, would require legislative changes since current acts contain no mandate for such work.

Option 3: Reduce the role of the SAES and strengthen the role of USDA in regional, national, and international PHT research by eliminating formula funds, leaving non-formula grants with agreed upon objectives as the source of Federal funds for SAES.

PROS

---Under this option no Federal funds for PHT research would be given to SAES without Federal accountability, program direction, and attention to effective management.

---All SAES would compete for Federal funds, making it more likely that they will be effectively utilized because they could be directed to those most capable of performing.

---Centralized program control would assure that Federal grant funds are utilized without duplication on problems of highest priority in the national interest.

CONS

---Many SAES could not maintain their research base without formula funding, the funds going to the already strong SAES and make them even stronger.

---The effect on the present pluralistic agricultural research system, visualized by the Congress in passing the Hatch Act would be negated, since SAES would cease to be partners with USDA and become paid performers for USDA.

---Weakening the SAES system would jeopardize the flow of agricultural research scientists trained to do PHT research, many of whom receive their undergraduate and graduate degrees, from Land Grant colleges.

---Ability of SAES to conduct adequate PHT research on problems of local and state-wide nature, as visualized with the passage of the Hatch ACt, would be diminished without formula funds.

---Overhead costs to administer non-formula grants would be high as compared to the costs of administering formula grants, reducing the amount of research that Federal funds would purchase.

---Elimination of formula grant authority would require legislative changes.

Option 4: Increase the role of the private sector by encouraging it, with or without additional incentives, to conduct more of the PHT research visualized by USDA as necessary and desirable in the public interest.

PROS

---Since wherever PHT research is conducted, the food and kindred product industries must apply the results of the research in their products or processes before the public can benefit, it is logical to have the private sector do both the research as well as the application of the results in the development of products and processes.

---The private sector focuses on product and process development with expected short-term pay-off; it spends on this about twice as much as public sources devote to PHT research.

---Since the private sector has insight into potential processes and products that would be competitively advantageous, they should have more of a hand in determining priorities in the research to be done.

CONS

---Private industry, for business reasons, places the public interest well below their own vested interests.

---The results of PHT research performed by private industry belongs to private industry, in contrast to that performed in or for public institutions and paid for by public funds, which belongs to the public; delineation of proprietary rights and public rights in PHT research done by the private sector under an incentives program would be difficult.

---Only the largest institutions in the private sector now conduct PHT research with their own resources making them the logical recipients of grants and/or other incentives to increase their efforts; such action would unfairly strengthen the monopolistic position of the large companies.

---History teaches that private industry is reluctant to make changes in a successful product even when new technology exists that would make changes possible in the public interest; performing more of the research to develop new technology would not likely induce the private sector to hasten its adoption in the public interest.

---The results of PHT research performed by the public sector are available to all in the private sector, large and small, and the contributions have been notably successful in the past; this contributes to maintaining competition which is in the public interest.

ISSUE 2: Are changes needed in the internal organizational structure of USDA to effectively conduct PHT research?

Findings

---In a very recent reorganization in USDA, the Science and Education Administration (SEA) as an operating entity was dissolved and the Agricultural Research Service (ARS), the Cooperative State Research Service (CSRS), the Extension Service (ES), and the Library were re-established as independent agencies; concomitantly, Human Nutrition Research was restored to the ARS.

---In the same reorganization, the Economic and Statistics Service was divided to re-establish the Economic Research Service (ERS) and the Statistical Reporting Service (SRS).

---The former head of the SEA is now Director of Science and Education, serving in a policy and coordination capacity equivalent to that of an Assistant Secretary of Agriculture.

---In ARS the functions of planning and operating remain separated and the Regional Administrators (the level of line officers just below the Administrator) remain stationed in the field.

---The function of planning and program development in ERS resides largely with the divisions and branches subject to the review of the Administrator and a small planning staff.

---The Regional Administrators in ARS are primarily managers with limited responsibility for program development or direction.

---In ARS there are no spokesmen, with line authority, for major program segments; e.g., crops research, PHT research.

Option 1: Maintain present organizational structure and division of responsibilities, meaning that:

---ARS, CSRS, ES, and the Library report to the Director of Science and Education who functions as an Assistant Secretary concerned with policy guidance and coordination of the agencies reporting to him but not with the day-to-day operations of the agencies reporting to him.

---In ARS the Regional Administrators continue at present field locations and continue as line officers concerned with management with limited responsibility for program formulation or direction.

---A Science and Education Coordinating Office would advise the Director of Science and Education, and coordinate USDA and SAES programs, but would have no responsibility for program direction or leadership.

---The former National Program Staff of SEA would advise and have responsibility for program leadership for the Administrator of ARS.

---CSRS would continue to administer formula grants to SAES and also have funds for non-formula grants to SAES and elsewhere.

PROS

---ARS, ERS, CSRS, ES, and the Library can operate most efficiently as separate agencies with a fully responsible agency head.

---A politically-oriented officer in the Secretary's office, whether called Director of Science and Education or Assistant Secretary, from whom the several agencies can receive policy guidance, is necessary and desirable.

---Having the Regional Administrators in ARS in the field places them closer to actual operations and the problems being approached through research than if they were to be located in Washington.

---Having the Regional Administrators of ARS concentrate on management of operations, leaving primary decisions with respect to program to a National Program Staff that has no authority to direct, is an effective system.

---Having no spokesmen with line authority for major segments of program avoids "empire building" by program leaders.

CONS

---Separation of the function of program selection and development from the function of program direction and management creates problems for line officers making running of the agency unnecessarily cumbersome, time consuming, and expensive.

---Having the first level of line officers below the Administrator in field locations remote from Washington deprives the Administrator of their daily advice and counsel and places them more under the influence of SAES Directors and their personnel as well as the political operators in the states, than it does under that of the Administrator and the Secretary of Agriculture.

---Having administration of both non-formula grants and formula grants in CSRS may tend to favor placement of non-formula grants at SAES.

---The constituents of USDA are better served if there is a spokesman for each of the major program segments, that is, a "Mr. Crops", a "Mr. Post Harvest Technology".

Option 2: Retain present organizational structure with certain changes, specifically:

---Abolish the office of the Regional Administrators of ARS.

---Re-establish in ARS the position of Deputy Administrator as a recognized scientist leader of a program segment with full delegated authority from the Administrator to direct and manage that segment; segments might be: Plant and Entomological Sciences; Animal Sciences; Soil Science and Engineering; Post Harvest Technology and Human Nutrition (these two either together or separate.)

---Re-establish a level of line officers below the Deputy Administrators in ARS, each of whom would be expert in and have responsibility for directing and managing programs nationwide in an appropriate field of work; for example, a Director of Crops Research, a Director of Animal Research, etc.

---Redirect the functions of the National Program Staff so it will serve the Administrator of ARS in a purely staff advisory capacity.

---Establish a National Program Staff in ERS to develop and coordinate research related to economic problems and policy issues utilizing the expertise in USDA and SAES.

---Re-establish an entity in ERS related to the economics of marketing and policy issues related to food and nutrition.

---Transfer administration of non-formula grants to ARS and ERS.

PROS

---The first level of line officers below the chief executive, ARS, belong in daily contact with the chief executive to facilitate a necessarily constant interchange of information, advice, and guidance.

---The Deputy Administrator should be a program leader in all respects, having responsibility for all aspects of his program segment, wherever they are located; he should be of such professional stature that he can command respect of superiors and subordinates.

---It is sound management and a service to the public the USDA serves that the level of line officers under the Deputies also be highly qualified professionals who are looked to at least nationally as authorities in their respective fields; it will be easier for those who seek the advice and help of USDA to find the expert in the area of their interest.

---It is good business to have a group (such as a National Program Staff) that has no operating responsibilities, to keep a weather eye on present and future researchable needs of agriculture, and feed advice to those who make program and budget decisions; it is equally good business to have this group fill the coordinating role since a knowledge of what is underway is essential to future planning and to the accountability that is mandatory in the use of Federal funds.

---Having a Deputy Administrator with "Post Harvest Technology" a part of his title, will provide a focus for and assure clear visibility in USDA and elsewhere of this most important segment of agricultural research.

---Having all non-formula grant authority in ARS and ERS will favor direction of these funds to high priority national projects that supplement or complement in-house programs and to institutions, whether or not Land Grant, that are best suited.

CONS

---Deputy Administrators belong in the field (to be Regional Administrators) where the problems are and the research is going on; they can communicate regularly and often with Washington as situations demand.

---The Regional Administrator needs to be first a manager; knowledge of the subject matter of the units he supervises in his region is secondary to management skills.

---For the same reason, the next level of authority, the Area Director, need not be a recognized scientist to assure that his particular area of the region is being managed properly.

Option 3: Remove post harvest technology research from ARS and place it in the Agricultural Marketing Service.

PROS

---Since the sphere of the Agricultural Marketing Service (AMS) encompasses the principal aspects of post harvest marketing services and regulation, it is logical to provide the Administrator with a research arm to support and improve his procedures and to serve the post harvest agricultural sector.

---Post harvest research would be a recognizable entity and have the organizational prominence and clearly identifiable leadership it deserves and does not have in ARS.

---Much of what is now called post harvest technology research was once in AMS where, under the experienced and sympathetic leadership that then existed, it proved to be a productive and highly regarded research organization.

---Post harvest research results can be put to work quickly to support the regulatory activities of the agency and serve the agricultural community without the necessity for establishing interagency arrangements.

---Post harvest problems that should be addressed by research can get quicker attention by an intra-agency research arm than by dependence on interagency arrangements.

---A research arm in USDA's Forest Service, primarily a regulatory agency, has functioned effectively and productively for many years and enjoys most favorable worldwide recognition as a research organization.

CONS

---Research in post harvest technology would be separated from other agricultural research in USDA and thus deprived of the easy collaboration with production research-oriented scientists that is sometimes desirable in solving post harvest problems.

---Placing post harvest research under Administrators whose responsibilities are less concerned with research than with action, would tend to make post harvest research less respected by scientific peers.

---Once moved to AMS, post harvest research might be directed primarily to practical, applied, more quickly resolvable problems in the post harvest area at the expense of equally important longer term basic research.

---Placing post harvest research in a non-research environment could place it under Administrators who are inexperienced in and unfamiliar with the ways of researchers and the problems unique to a research organization, and hence less sensitive to them.

---Placing post harvest research in AMS could politicize it so that research goals and directions could change with each change in administration.

ISSUE 3: Is the present national priority-setting system working well for agricultural research and particularly for PHT research?

Findings

---The priority-setting system for food and agricultural research has not been working well at the OMB and Congressional levels, particularly since World War II; agriculture-food research and development support has decreased relative to total research and development support at the Federal level.

---Within food and agriculture, the present system is not working well with respect to PHT research (which addresses researchable problems between the farm gate and the ultimate consumer where about two-thirds of the total value is created). Relative support of PHT research has declined at the same time that the relative importance of a strong PHT research program has increased.

Option 1: Continue the present system of priority-setting and allocation of Federal funds for PHT research.

PROS

---Priority-setting based on existing general directional goals (1966 Long-Range Study) has yielded excellent results as manifested in a highly efficient and progressive food sector.

---PHT projects proposed by the Executive Branch and authorized by the Congress each year are the resultant of the thinking of research leaders in USDA and SAES and reflect, by and large, the urgent research needs at that time.

---Primary emphasis on production research in agriculture is, after all, traditional; why rock the boat by developing a new system of priority-setting when there is a possibility that PHT research might wind up with funds now going to production research.

CONS

---The present system tends to perpetuate the establishment, including its components, without regard to the changing relative importance of the various sectors of the economy.

---The present system gives lip service to emerging issues without expecting substantial change in the allocation of resources for research.

---Under the present system the government has no guides for determining whether proposed budgets are directed to the most urgent national needs.

Option 2: Introduce more objectivity into the priority-setting system to assure that appropriate consideration is given the relative importance of value created, employment, and consumer expenditures in the agricultural-food sector and the relative importance of the post harvest subsector based on these criteria.

PROS

---A system that would afford objective consideration of the economic factors operating in the post harvest subsector would reveal that PHT research in recent years has been undersupported relative to production research.

---Such a system would insure that resources are allocated proportionally to those researches that have greatest potential for enhancing consumer benefits through increased productivity of natural resources, capital investment, and labor.

CONS

---Many of the things that occur in the post harvest sector appear to be less concerned with agriculture than they are with commerce and trade; why give them equal weight with production research when it comes to preparing budgets.

---Production research funds are already less than they should be in light of the many production problems that remain unsolved; why encourage examination of the whole picture and run the risk of having production funds siphoned off to increase PHT research.

---An objective system would tend to preclude or restrict the exercise of subjective judgment on the part of administrators and planners.

---It is difficult to justify changing a system that is a proven success.

Option 3: Develop a system of explicit and quantified research goals (including PHT research goals) with specific target dates for accomplishment.

PROS

---Such research goals, regularly kept current, made publicly available, and used as a guide in budget formulation, should serve to give OMB, the Congress, and the interested public a sense of direction with respect to the use of Federal funds for PHT and other agricultural research.

---The USDA, OMB, and Congress would have more specific estimates of benefit with which to compare various proposed expenditures.

---More emphasis would likely be directed to projects with high probability of success since administrators could be held accountable for failures.

CONS

---Developing, keeping current, and making publicly available a national research agenda and priorities that are consistent with expected potentials of research underway and with the nature and magnitude of problems visualized in years ahead, is a complex and costly undertaking requiring continuing attention by and adequate support for those fully qualified to do it.

---Explicit and quantified goals would be highly transitory in character.

---High-risk research leading to breakthroughs would likely be avoided.

ISSUE 4: How should Federal funds for PHT research be allocated between USDA in-house programs and formula (and other) grants to the SAES?

Findings

---With the passage of the Hatch Act a century ago, the Congress determined that a pluralistic agricultural research system, consisting of the USDA and the SAES, could be vigorous only if Federal funds were to be provided to the SAES.

---The fraction of the total Federal funds for PHT research going to the SAES in 1979 was about 25% and to in-house research of USDA, 75%.

---While the CSRS is USDA, in its efforts to coordinate the use of Federal funds in the SAES, is aware of the nature of PHT research in the SAES, it has no authority to plan or direct the PHT research performed with formula funds or to influence the proportion of total formula funds that are devoted to PHT research.

---In addition to formula grants, CSRS also administers a fund for non-formula (competitive) grants, most of which flow to the SAES.

Option 1: Maintain present practices in the distribution of Federal funds for PHT research between USDA in-house and SAES programs.

PROS

---There is no need to change a system that has had a history of working well.

---Under the present system the level of formula funds is determined annually by negotiation between USDA, SAES, and the Congress,

---The SAES directors have control of their own programming with minimum interference by the Federal bureaucracy.

---Without the availability of Federal funds in predictable amounts through formula grants, many SAES could not maintain their research base.

---Changing the administrative procedures would create controversy and require legislation.

CONS

---Formula funds represent a significant fraction of the total Federal funds for PHT research that cannot be directed to problems deemed to Congress to be most important in the national interest.

---There is potential for duplication as well as a potential for spending Federal PHT research funds on relatively trivial problems in a system that does not plan in advance the use of all of its resources.

---In the administration of competitive grants, there could be a tendency for CSRS to favor the SAES, a situation that would be less likely to occur if they were administered by ARS and ERS and used in the institutions with competence to perform research that supplements and complements the inhouse PHT research programs of USDA.

---There is a waste of time and effort in the vying between USDA and SAES for Federal funds in the annual budget process; this detracts from the cooperative relationship between USDA and SAES that the Hatch Act was designed to foster.

Option 2: Set Federal funds for formula grants at a fixed percentage of total Federal funds for agricultural research and set funds for PHT research at a fixed percentage of the formula funds.

PROS

---Proceeding in this manner would end the vying for Federal funds between USDA and SAES at the expense of each other.

---Under this system the USDA and the SAES (through CSRS) could concentrate on jointly developing the strongest possible agricultural research agenda, including the strongest possible PHT research agenda; such a national agenda cooperatively arrived at, that addresses the pressing issues and impresses Congress with its potential, is more likely to encourage the level of support that both USDA and SAES are seeking.

---Fixing the percentage of total formula funds to be used for PHT research will reduce the tendency in SAES to favor production research, at the expense of PHT research, in their use of Federal funds.

---Lobbying by SAES before Congressional Appropriation Committees could be directed to the need for the total program for use of Federal funds rather than just to their particular stake in it.

CONS

---Change in the present system would require legislation and the process would be likely to create controversy.

---Federal appropriations should be authorized on the merits of the individual items, not as a fixed percentage of a total.

---Assurance of the receipt of a fixed percentage of Federal funds each year might tend to cause SAES to become less rigorous in approaching their responsibilities.

ISSUE 5: What should the source of funding be for PHT research in the United States and are present levels adequate?

Findings

---PHT research in the U.S. is now supported by Federal funds appropriated to USDA and other Federal agencies (used in in-house programs of USDA, allocated by formula to SAES, and provided as competitive grants to SAES and other research institutions), by State funds appropriated by State legislatures and used in the State, and by private funds spent in the research laboratories of private companies and used to support research in SAES and other research institutions.

---Equity issues clearly favor Federal funding for PHT research because the results of such research predominantly affect interstate commerce and benefits flow mainly to consumers.

---PHT research in the private sector will continue to be of such nature and funded at a level such that the company concerned will derive competitive advantage in the short run; private industry does not find it advantageous to do research solely in the national interest or in pursuit of long-range national goals.

---No way has yet been found to determine how much is just enough (adequate) research in agriculture (or any other field); too much is likely to lead to waste of funds and carelessness in program selection; too little is likely to jeopardize the future of U.S. agriculture.

---Since World War II, research in USDA has been the least well supported of all of the Federal agencies which do research; this contrasts with the previous half-century when USDA claimed the major share of the Federal research dollar. Many believe that this foresight on the part of the executive and legislative branches years ago is responsible for the emergence of U.S. agriculture as the most successful enterprise of all time.

---Constant dollar Federal expenditures for PHT research decreased 6 percentage points between 1966 and 1979 and in 1979 were 26% of the Federal expenditures for all agricultural research.

Option 1: Maintain present sources and public funding levels for PHT research which means that Federal resources would provide about 73%, State sources, 27% of public funding. Total public funds for PHT research would be about $210 million in current dollars, or about $88 million in constant dollars. It is assumed that industry would continue to invest about $185 million (constant dollars), its 1975 level, in food and kindred product research.

PROS

---It is logical and desirable that Federal and State governments and the private sector retain their current options concerning the level at which they deem it necessary to fund PHT research.

---While the current level of PHT support is lower than many believe it should be, funds are sufficient to permit research on the problems of highest priority; limited funding tends to increase efficiency in the use of funds.

CONS

---Since consumers derive most of the benefit from PHT research, Federal sources should defray a greater fraction of the total public funds now being spent for PHT research to insure equity between benefits and costs.

---The recent constant dollar decrease in the level of Federal funding of PHT research means that the capacity of the Federally supported research enterprise, because it is not keeping pace with inflation, is being eroded.

---While the disciplinary advantages of austerity are recognized, budgets that are too tight to permit a reasonable amount of exploration in areas that may provide long-range benefits, can cost the U.S. its world leader position in matters agricultural.

Option 2: Substantially increase present Federal funding levels for PHT research.

PROS

---All 230 million Americans derive greater return from Federal tax dollars spent to support agricultural research, including PHT research, than they do from their State tax dollars or the support they provide private industrial research which is included in the cost of commercial products they purchase. An increase in Federal funds for all agricultural research would automatically increase the level of PHT research if, as a matter of policy, the latter were to be fixed at a set percentage of the former (see Issue 4, Option 2).

---In considering the above, it should be recognized that the present percentage (26%) that Federal PHT research supported by Federal funds is of the total Federal funds for all agricultural research, is smaller than it should be in light of the relative urgency and importance to the farmer and the consumer of the researchable problems in the post harvest sector.

---Funds over and above those needed for research on the bare essentials, should always be provided any virile research organization to permit it to explore areas that promise future benefits and breakthroughs.

CONS

---When funds are plentiful, management becomes lax and inefficient.

GLOSSARY OF TERMS

ACS -

Agricultural Cooperative Service, U.S. Department of Agriculture.

Affluence -

Defined as a relatively high level of living of a populace based on a relatively high level of productivity.

Aflatoxin -

The particular mycotoxin produced by the fungus *Aspergillus flavus*.

Ag-food -

An acronym for agriculture-food.

Air classification -

Separation of the components of a particulate mixture on the basis of particle density, size, and other aerodynamic properties.

Amylase -

An enzyme capable of converting starch to sugar.

AMS -

Agricultural Marketing Service with primary responsibility for administration of Federal laws pertaining to grades and standards for agricultural commodities.

AREC -

Agricultural Research Experimental Center.

ARS -

Agricultural Research Service of the U.S. Department of Agriculture

ASCS -

Agricultural Stabilization and Conservation Service, U.S. Department of Agriculture.

BAIC -

Bureau of Agricultural and Industrial Chemistry, once an agency of the U.S. Department of Agriculture.

Biodegradable -

Capable of being broken down by bacteria or molds.

Bisulfite -

A chemical commonly used to reduce or prevent microbial spoilage of foods.

Brix -

A unit to measure sugar concentration in solutions.

Cartel -

A collection of sellers acting as one.

CO_2 -

Carbon dioxide

Controlled atmosphere CA -

An environment in which the oxygen and carbon dioxide levels are controlled, and the temperature as well, as in a cold storage room.

CRIS -

Current Research Information System, ARS, U.S. Department of Agriculture.

CSRS -

Cooperative State Research Service of the U.S. Department of Agriculture.

Dehydrofreezing -

Freezing a product which has been partially dehydrated.

Demand -

A schedule of quantities buyers will take related to market price--generally increases or decreases according to a described mathematical function.

Efficiency -

Output from a product enterprise related to inputs--increased output relative to inputs is interpreted as increased efficiency. Specifically, labor efficiency is the output per unit of labor input.

18-Wheeler -

Refers to large and generally long-haul trucks.

Endogenous product -

A chemical made within the living organism itself.

Entomology -

The study of insects.

EPA -

Environmental Protection Agency.

"Epoxidized" oils -

An oil in which extra oxygen has been introduced chemically.

Ethoxyquin -

A chemical having antioxidant activity.

ERS -

Economic Research Service, U.S. Department of Agriculture.

Ethylene -

A colorless, odorless gas that stimulates the ripening of fruits and vegetables.

Exchange made -

A point along the marketing channel where exchange of ownership occurs.

Fatty acids -

Chemicals that occur in bound form and comprise the major part of animal fats and vegetable oils.

Finish -

A chemical treatment applied to fabrics.

Foam mat drying -

A process in which a material such as orange juice is dried to a readily soluble powder (collapsed foam) by adding a substance, such as a proteinaceous material, that makes the solution foam when dry air is passed through it.

Fungistat -

A material that checks the growth of fungi such as molds.

Gasohol -

A 90:10 mixture of gasoline and ethyl alcohol.

Glanded cottonseed -

Cottonseed that contains pigment bodies (glands).

Guayule -

A shrub, adapted to growing conditions in southwestern United States, that is presently being investigated as a domestic source of rubber.

Hand -

The feel or tactile reaction to a textile fabric.

Herbicide -

A chemical that inhibits the germination or growth of plants.

Innovation -

A change--usually improvement--in a production/marketing activity.

IRI/RC -

Industrial Research Institution/Research Corporation.

ISX -

Insoluble starch xanthate, a chemically modified starch.

Joint Council on Food and Agricultural Sciences -

Council established by The Food and Agriculture Act of 1977.

Kindred products -

Other products such as cotton, wool, tobacco, alcohol, and industrial nonfood products made from agricultural commodities.

Market channel -

The movement and change in form of products through the marketing system.

Market exchange -

Exchange of ownership of commodities generally inferred to occur in organized markets.

Marketing -

Defined to include all physical and economic activities in moving ag-food products through commercial channels including exchange of ownership.

Market structure -

Refers to a number and location of buyers and sellers in the market.

Meat analogs -

Meat-like products based on plant proteins and fats.

Monopoly-monopsony -

Refers to one seller (monopoly) and/or one buyer (monopsony) or a market dominated by one buyer and/or one seller.

Mycologist -

A scientist specializing in the study of microorganisms such as fungi and yeasts.

Mycotoxins -

Chemicals produced by microorganisms (fungi) that are toxic (poisonous) to animals.

Nontarget organisms -

Plants, insects, and other organisms that should not be affected by herbicides or pesticides; e.g., crops, bees.

O_2 -

Oxygen.

OPEC -

Organization of Petroleum Exporting Countries.

Osmovac drying -

Removal of water from fresh fruit pieces by immersion in concentrated sugar solution, drawing water from fruit into the sugar solution by osmotic forces.

PARIS -

Program and Resources Information System.

Petrochemicals -

Chemicals derived from fossil fuels such as petroleum.

PHT -

Post harvest technology defined here to include all technology related to the ag-food sector after leaving the farm.

Pathogen -

A microorganism that causes a disease.

PL-480 -

Public Law 480, an Act of Congress authorizing the sale or donation of food to other nations accepting payment in foreign currency and using it for U.S. purposes abroad.

PMA -

Production and Marketing Administration, once an agency of the U.S. Department of Agriculture.

Polymer -

A complex chemical consisting of repeating units of a simpler chemical; starch, for example, is a polymer of the sugar, glucose.

Polysaccharides -

Saccharides is the chemical name of sugars. Generally, the simple sugars are called saccharides and those consisting of repeating units of one or more simple sugars are called polysacchairdes.

Pomology -

The study of fruits.

Price discovery -

The mechanism by which demand and supply forces interact in the market to determine an exchange price.

Research and Marketing Act of 1946 (PL79-733) -

An act of the United States Congress in 1946 for funding ag-food research with increased emphasis on marketing.

Resource allocation -

The distribution of resources (land and other raw materials, capital and labor) among productive enterprises.

Revenue flow -

Related to the flow of final consumer expenditures for ag-food commodities backward through the marketing channels to the participants in the production-marketing system.

Saccarification -

The conversion of starch to fermentable sugars.

SAES -

State Agricultural Experiment Stations of the Land Grant Universities and others designated by Congress.

Sector -

Refers to a major component of the United States economy such as the ag-food sector. A subsector in a component of a sector such as the marketing subsector of the ag-food sector.

Senescence -

The process of aging.

Sodium benzoate -

A chemical used in foods as a mold inhibitor.

Spatial -

Refers to the space or geographic aspects of markets.

Supply -

A schedule of quantities delivered by producers related to market price--technically, the aggregation of marginal cost functions of producers.

Tall oil -

A by-product of papermaking.

Technology -

A group of related technical processes in economic enterprises.

Temporal -

Refers to a time or seasonal diversion of markets.

THPOH -

A phosphorus-containing chemical whose name is given in reference 263.

Top -

A continuous strand of wool fibers formed after straightening tufts by combing.

USDA -

United States Department of Agriculture.

Users Advisory Board -

The National Agricultural Research and Extension Users' Advisory Board, established by The Food and Agriculture Act of 1977.

VPI and SU -

Virginia Polytechnic Institute and State University.

Xanthophyll -

A yellow pigment present in green plants.

Commissioned Paper VIII

THE ROLE OF U.S. FOOD AND AGRICULTURAL RESEARCH IN INTERNATIONAL DEVELOPMENT

William R. Furtick

Office of Technology Assessment

February 1981

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Executive Summary

I. Introduction

U.S. assistance to solve the technical problems and help overcome socio-economic constraints to insure adequate food production and consumption in developing countries should receive a very high priority. There is strong potential for serious damage to the U.S. economy if these nations do not provide adequate food production and availability to meet their increasing needs caused by rapid population growth and rising income levels. Political and economic stability in these countries is of high strategic importance for the United States and should be ranked along with rebuilding military capability and restoring economic stability to the U.S. economy as top priorities for the immediate future.

The United States is increasingly dependent on these countries for a growing amount and diversity of raw materials to sustain the industrial sector. Instability that could result from food shortages or drastically increased prices would seriously enhance the chance for major defaults on loans to the American and international banking community. Major loan defaults could seriously jeopardize the stability of the international monetary system and solvency of major U.S. banks. Because the U.S. economy is closely tied to international markets, rapid rise in commodity prices due to food shortfalls would trigger major increases in the rate of U.S. inflation.

The low-income countries, already hardest hit by rising oil prices, are also the ones falling behind population growth in rate of food production. The United States has spent approximately $30 billion in food aid for these countries the past three decades. With increasing need and rising food prices the cost of this food aid is escalating.

To overcome these problems, the countries must be provided with effective technical assistance to not only produce their own food, but also improve their incomes through increased production of export crops such as timber, coffee, tea, cocoa, rubber, palm oils, spices, etc.

For the United States to provide effective assistance will require a complete reorganization of the foreign assistance program. Recommendations are made for this purpose.

In the 1940s, 1950s and 1960s, the foreign assistance program concentrated more on technical assistance to build local human and institutional resources. These efforts were very effective and have had lasting impact. Enough knowledge has been gained in this process and since, to launch an effective new program on the foundations started during these years.

The U.S. assistance program in the 1970s shifted more heavily to capital transfer programs with questionable impact. These need to be greatly curtailed, the scope of the assistance program narrowed and more clearly focused. These countries have adequate alternative sources for needed capital transfer.

Although the role of research is basic to solving the problems of sustained agriculture in the tropics, its success is intimately tied to a variety of interrelating aspects of the assistance program. Therefore this paper recommends comprehensive reorganization of AID and the way assistance is carried out by USDA and other government agencies, American universities and non-government organizations. It also recommends a special study of ways to remove specific government regulations that are preventing more effective use of the private sector in assisstance programs.

II. The Current Status of International Agricultural Development

During the colonial era prior to World War II, most of the colonies were self-sufficient in food and exported surpluses. They produced large amounts of plantation crops such as cotton, tea, coffee, rubber, spices, etc., for world markets. With decolonization after the war, major aid programs were launched by the United States, the former colonial powers, and the new UN system to help these newly independent countries build infrastructures such as roads, schools, and water systems; the needed institutions to provide research, extension education; and the services need to produce, process, transport, store and market the products of agriculture to feed an increasing population and maintain the sale of plantation crops for export earnings. Public health programs helped reduce mortality rates, but emphasis on transferring inappropriate temperate zone food production technology proved unsuccessful. Overemphasis on programs to extend American technology retarded growth in local production and use of American food surpluses as foreign aid depressed local markets. These actions slowed the development of adequate local research capability and made local food production noncompetitive with concessionary food aid. The end result, particularly in the lowest income developing countries, was for food production and agricultural modernization to lag, causing increased dependence on food aid.

The international community with substantial leadership from the Rockefeller and Ford Foundations recognized the need to develop international and national research institutions to develop the technology needed for the tropics. This led to the UN organizations--World Bank, UNDP and FAO--establishing a donor group, CGIAR, to fund this coordinated international research network. The primary U.S. contribution was early agreement to fund 25 percent of the core program.

The need now is for the United States to link its scientific capacity into this major national and international research network to both contribute and gain from the new knowledge that they are generating. The assistance also needs to shift toward improving the local research and development networks in the individual countries.

III. The Role of Research and Technology as a Primary Motive Power in Agricultural Development

The high level of development and productivity of U.S. agriculture has been the result of relatively large investments in research coupled with extension programs to transfer the results to farmers, and a comprehensive educational system in agriculture that could provide training needs from farm skills to those of the scientists. Research has had a high payoff and return on investment. It has now been adequately demonstrated that the same is true in the tropical countries that make up most of the developing world.

The U.S. efforts to assist in developing appropriate technology for these countries has been handicapped by the lack of adequate tropical agricultural expertise in the U.S. system. The Section 406 Dole/Matsunaga amendment to the Food for Peace Act of 1966 was aimed at correcting this deficiency. The assignment of administrative responsibility to USDA that viewed international activities as a conflict of interest to their domestic roles resulted in Section 406 not being implemented even on a token basis until 1975. Even the current limited implementation has been the result of actions by the university community through the Congress rather than by USDA until very recently.

Early effort by U.S. assistance programs focused too heavily on developing extension programs to transfer American technology. Effort now needs to refocus on developing local research capabilities to develop or modify technology to suit local conditions. The United States has the largest research and technology capability to provide this type of assistance. Earlier efforts predominantly prior to 1970 demonstrated this could be done. Shifts away from this emphasis and failure to institutionalize the U.S. efforts by USDA, American universities and other organizations require total reorganization for the use of U.S. scientific capacity in foreign assistance.

IV. Examination of Past and Current Instruments for the Use of U.S. Science and Technology in International Food and Agricultural Development

USDA has not played an active role in the international agricultural field until recently because of a perceived conflict of interest with domestic roles. However, many of the USDA staff have been very active in supporting roles through interagency PASA agreements with AID. This has been handicapped by lack of recognition for these contributions by USDA. Those that accepted PASA assignments were often passed over for promotion and new assignments which retarded career development. As a result, USDA has acted increasingly as a hiring hall to obtain outside talent for AID because it was faster and easier to do this on a PASA agreement than AID's complex contracting procedures with universities or the private sector.

The AID efforts were heavily focused in the 1950s and 1960s on institutional development in the developing countries. These were carried out by numerous and often large contracts with American universities or PASA agreements with USDA. These efforts were accompanied by large participant training programs used to train LDC staff in the United States. During the past decade these generally successful programs have been de-emphasized until recently.

The Title XII Amendment to the Foreign Assistance Act of 1975 was an attempt to link U.S. expertise in universities into the needs of the assistance program. It has had difficulty fulfilling the expectations of the legislation because certain aspects of the legislation tended to create conflicts between the university community and AID.

Most Aid agricultural research aimed at international development is carried out through centrally funded research contracts, mostly to American universities. These are being funded in areas of high priorities such as tropical soils, pest management, sorghum and millet, peanuts, etc. They often involve cooperative research programs linking scientists in various American universities, national research centers of developing countries and CGIAR-sponsored international agricultural research centers. Title XII programs require each of the participants to put in some matching contribution from non-U.S. Federal funds. The largest AID support of research is to support institutions in developing countries through USAID missions. These are contracted to American universities or other organizations for implementation.

The USDA has recently developed a joint agreement with the National Association of State Universities and Land Grant Colleges (NASULGC) to implement a series of bilateral technical and scientific agreements with middle-income non-AID recipient countries. Efforts by other agencies are also reviewed, including the National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF) and the National Academy of Science (NAS). The research activities of the private sector are also examined.

V. Evaluation of Alternatives for More Effective Use and Funding of U.S. Science and Technology for International Agricultural Development

The past and current malfunctions and organizational problems of the American foreign assistance program are examined in some detail. These are caused by lack of a cohesive policy and program development structure that can coordinate the activities of more than a dozen units of AID dealing in a non-coordinated way with food and agricultural programs. The percent of the AID budget devoted to the agricultural sector has gone from 19 percent to 50 percent in the last decade while professional staff have declined 78 percent. To correct these problems will require major increases in staff trained in technical areas of agriculture and major reorganization.

The reorganization recommended proposes the establishment of a new administrative structure designated the International Food and Agricultural Development Administration (IFADA). This would bring into a cohesive unit all the fragmented programs scattered throughout AID to permit sound development of overall policies, strategies, goals, objectives and programs on a sustained basis.

In order to integrate this effort with supporting areas of public health, education and population planning, it is proposed that all these areas be placed under a new Deputy Administrator for Technical Assistance Programs. A new career technical officer position in each USAID mission as Deputy Mission Director for Technical Assistance is proposed to link this effort to the USAID mission activities.

Specific central support programs are recommended in planning, monitoring and evaluation; statistical and data management; information storage, retrieval and evaluation; and related support services required for effective coordination and evaluation across sectoral areas.

To develop adequate career international staff in USDA, American universities, and other agencies and non-government organization contractors, a new block grant program is proposed.

This would require contractors to commit to long-term efforts within specific guidelines that would assure quality delivery. Based on these commitments, AID would provide five-year roll forward block grant guaranties based on 70 percent of the previous five-year average of contracts. AID would pay annually the cost of all contract business that exceeds the amount of the block grant.

In order to increase mobility between government, universities and other cooperators, new uses of the IPA are recommended.

To increase the supply of professionals trained in international agriculture development, a series of special programs are recommended to be linked with the activities of IFADA and its contractors.

An alternative for placing IFADA in USDA is developed, but recommended only as an alternative.

Specific recommendations are made to substitute these new approaches for Title XII and for use of programs in other agencies in support of these efforts.

Establishment of a special task force to develop the details of IFADA and oversee implementation is recommended.

Major reevaluation, refocusing and reductions in the scope of the U.S. foreign assistance program are recommended. These reductions should be more than adequate to provide the new staffing and resources needed to implement IFADA and related programs recommended.

VI. Examination of the Current Status and Value of Interchange of New Technology between International and National Centers and U.S. Research Agencies

Some of the declining capabilities of the U.S. agricultural research capacity are contrasted with the development of excellent facilities that are well equipped and staffed with well trained young scientists in emerging national and international research institutions. The aging of American facilities, equipment and limited entry of vigorous young scientists makes it important for the sake of U.S. science to build close linkages overseas. In the basic science research areas that are becoming increasingly important to solve future problems, the American scientists are far in the lead and have fared better in funding in recent years than agricultural research.

VII. The Implication for Agriculture and Agribusiness of International Agricultural Development

The general support for prevention of hunger by the general public is contrasted with the fear of competition voiced by some in the farming and agribusiness community. The case is developed that these fears are largely without basis because agricultural development in the Third World has been found to increase demand for U.S. commodities in greater variety, and for other American goods and services. Thus, aid to help agricultural development has a favorable long-term impact on both American agriculture and industry.

Glossary of Terms

Adaptive Research - The process by which a new research finding, such as a new crop variety, is studied in the particular climatic, soil or farm conditions where it is to be grown. This includes such things as planting time, amount and kind of fertilizer, and kind of insects that need to be controlled in a specific area where the new variety will be planted.

Animal Health Care Products - These include serums for vaccination against diseases, insecticides to control external parasites such as flies, ticks, etc., and products to kill internal parasites such as intestinal worms.

AVRDC - Asian Vegetable Research and Development Center. A center affiliated with the CGIAR supported centers located in Taiwan.

Banteng Cattle - A native type of small cattle from a localized area of Indonesia with rapid growth rate, high disease and pest resistance that do well in hot tropical areas. They are a species, not a breed of cattle.

Basic Research - Research aimed at discovering new knowledge such as how plants convert the energy of sunlight into the manufacture of all the chemicals required in their growth through a process called "photosynthesis." The purpose of this research is to obtain new knowledge as the primary objective, not to utilize the new knowledge to solve specific problems of economic benefit, even though once discovered, this new knowledge may end up having a wide variety of economic benefits.

Bilateral - An agreement or operation between two parties such as agreements between the United States and another country on a particular matter.

Biological Nitrogen Fixation - A term used for processes by which organisms such as bacteria or fungi take nitrogen out of the air and change it into a form that plants can use. Nitrogen is one of the most important plant nutrients as it is the basis of all protein compounds. Although abundant in air, plants cannot use nitrogen from the air.

Career Track - A series of job assignments of increasing responsibility or importance used as a means of providing opportunities of sequential advancement for employees of an organization with particular types of skills.

CIAT - The acronym for the Spanish name of the International Center for Tropical Agriculture located in Cali, Colombia. A CGIAR sponsored center.

CIMMYT - The acronym for the Spanish name of the International Center for Research on Corn and Wheat. This is one of the CGIAR sponsored centers located near Mexico City, Mexico.

CIP - The acronym for the Spanish name of the International Potato Center. One of the CGIAR sponsored international research centers specializing in research on potatoes located near Lima, Peru.

Delivery System - As used in this paper, it refers to the procedures by which the results of research reach the end users so they can utilize the new knowledge or technology. This usually involves various agencies and procedures which differ from country to country. In the United States, it involves branch experiment stations or demonstration farms where farmers can view the results and an extension service that publishes information, holds educational meetings and visits individual farmers.

Developing Countries - These are utilized in this paper interchangeably with "Third World Countries" to distinguish them from the high-income industrial countries in Europe, the United States and Canada, Australia, New Zealand, and Japan. USAID uses this to designate countries with average per capita incomes below a specified point that makes them eligible for AID funds. Those above this arbitrary line are referred to as middle-income countries to differentiate them from the industrial countries first indicated.

Donors - As used in this paper, refers to those countries or organizations that make major contributions directly or through group action to support international development activities.

Extension - As used, refers to non-formal educational programs to assist farmers, their families or those that work with farm families to obtain information and skills to improve their capabilities.

FAO - The Food and Agricultural Organization of the United Nations. One of the specialized agencies of the UN system devoted to international assistance in the particular area of its title. FAO is headquartered in Rome, Italy.

Genetic Engineering - A new term used to designate the process by where genetic material is transplanted from one organism to another to give new types of genetic characteristics to the recipient organism. So far this has been used primarily in lower organisms such as bacteria, but may be used eventually in plants and animals.

Germ Plasm - Used to designate special genetic properties of seed or animal breeding stock that are used in breeding programs to produce improved strains or varieties.

Infrastructure - The internal parts required to make a county, locality or organization function efficiently. These include such things as schools, roads, electricity, police, storage facilities, railroads, etc., or in the case of an organization, committees, offices, facilities, etc.

Institution Building - A term used for assistance program designed to start or improve organizations such as universities, experiment stations, extension services, information services, regulatory agencies, credit agencies, etc., required to provide services needed by the rural communities in a country.

ICARDA - International Center for Agricultural Research in Dryland Areas; a CGIAR center for Middle East agriculture centered in Syria and Lebanon.

ICIPE - International Center for Insect Physiology and Ecology; an affiliate CGIAR center located in Kenya.

ICLARM - International Center for Living Aquatic Resource Management. An affiliate CGIAR center located in Manila, Philippines, dealing with fish and other aquatic organisms of economic importance.

ICRISAT - International Center for Research on the Semi-Arid Tropics. One of the CGIAR centers located near Hydirabad, India.

IFC - The International Fertilizer Center located in the United States as an outgrowth of the Tennessee Valley Authority dealing with the manufacture and use of fertilizer. It is affiliated with the CGIAR system.

IITA - International Institute for Tropical Agriculture. A CGIAR center dealing with the humid tropics located in Ibaden, Nigeria.

ILCA - International Livestock Center, Africa; a CGIAR sponsored center on livestock production located in Ethiopia.

ILRAD - International Livestock Research, Animal Diseases; a CGIAR center located in Kenya.

INTSOY - An affiliated CGIAR center dealing with soybeans headquartered at the University of Illinois, Urbana.

IRRI - International Rice Research Institute; a CGIAR sponsored center in Los Banos, Philippines.

ISNAR - International Service to National Agricultural Research. This is the newest CGIAR center established to assist the LDC national research organizations develop and to be able to more fully collaborate with the international centers. It is headquartered in Amsterdam, Netherlands.

International Network - This is a widely used current term to designate a multi-country cooperative program with common objectives in which there is joint planning, assignments of areas for primary responsibility, coordination of activities, reporting on results and decisions on follow-up activities. These networks may be partly or wholly funded from one source or entirely by the individual collaborators.

Limited Resource Farmer - A more descriptive term than small farmer because a farmer with inadequate resources may be on farms of considerable size variation. Some high-income farms may be smaller than low-income farms, so size is less descriptive.

Mission-Oriented Research - Research aimed at the solution of a well-defined problem of economic importance such as the control of a specific insect problem, curing an animal disease, etc.

Multilateral Aid - The aid programs that represent contributions from numerous donors, but act in the same manner as would a single donor. UN agencies are good examples.

Ova Culture - New techniques utilized to keep newly fertilized ovum alive outside the body of animals. This is now being utilized in oval transplants from one mother to another or where ovum are removed from the ovary of, say, a woman, fertilized outside her body and returned to her uterus for development. If procedures could be developed to substitute for the female uterus, then the baby animal could be grown to normal birth stage outside the body of the mother.

Sea Grant - A Federal program established to develop a series of American universities that provide the same research and educational services to develop marine and aquatic resources as established for agriculture and related areas under the Land-Grant Act.

Senescence - The process of aging.

Small Ruminant - Sheep, goats or any other multi-stomach, grass-eating animal smaller than cattle and buffalo.

UNDP - United Nations Development Programme. This acts as the aid agency for the United Nations much as AID does for the United States.

I. Introduction

U.S. assistance to solve the technical problems and help overcome socio-economic constraints to insure adequate food production and consumption in developing countries should receive a very high priority. There is strong potential for serious damage to the U.S. economy if these nations do not provide adequate food production and availability to meet their increasing needs caused by rapid population growth and rising income levels. Political and economic stability in these countries is of high strategic importance for the United States and should be ranked along with rebuilding military capability and restoring economic stability to the U.S. economy as top priorities for the immediate future.

The United States is increasingly dependent on these countries for a growing amount and diversity of raw materials to sustain the industrial sector. Instability that could result from food shortages or drastically increased prices would seriously enhance the chance for major defaults on loans to the American and international banking community. Major loan defaults could seriously jeopardize the stability of the international monetary system and solvency of major U.S. banks. Because the U.S. economy is closely tied to international markets, rapid rise, in commodity prices due to food shortfalls would trigger major increases in the rate of U.S. inflation.

Research is basic to the solution of problems preventing adequate levels of sustained food production and consumption in the tropical regions where most developing countries are located. This paper adds an international dimension to the OTA study on "U.S. Food and Agricultural Research," which is primarily domestically oriented. It examines the past, present and potential role of the U.S. agricultural research establishment in international food and agricultural development. The United States has made major annual expenditures in the food and agricultural sector of the foreign assistance programs since the close of World War II, but there has been a failure to utilize the U.S. agricultural research establishment in an organized manner to support this effort. The United States Department of Agriculture (USDA) and the land-grant universities have both made major research contributions to this effort. However, their scientific capacity to deal with international problems or link into the research findings of overseas research organizations has not been on an organized program basis. In spite of longstanding receipt of substantial contracts, grants or interagency pass-through funding, nearly all expenditures are approached on an ad hoc basis for each grant or agreement. This approach has prevented the efficient use of these rather large annual funding transfers. To do this would require their use to develop a career track and reward system for this type of service. The result at both the Federal and university levels has been failure to develop a significant pool of available scientific staff with recent overseas experience and a reward system that does not penalize career development if used in overseas activities.

Because of the vast domestic market for U.S. food and agricultural technology developed and marketed by the private sector, most companies have not devoted significant research efforts directed toward products specifically for sale in international markets. During the last decade, many of the larger firms have increased research and development activities in direct support of expanding international divisions. Most of these efforts have been directed toward hard currency markets. However, recent internal revenue decisions and other disincentives at the Federal level, in contrast to significant incentives used by nearly all foreign competitors, has caused reassessment and in some cases, reduction or elimination of these efforts. The United States now, as never before, needs added trade to maintain a favorable balance of payments due in its burgeoning oil imports. Serious disincentives for the American private sector make expanded trade difficult or unattractive.

It is in the United States interest to sustain current technological leadership in food and agriculture which permits the export of large amounts of food, agricultural machinery, supplies and technology. Assisting the poorest nations to produce more of their basic food needs could also reduce the food aid expenditures required to prevent starvation. This has represented about $30 billion dollars of U.S. food aid since the close of World War II. Because of rapidly rising world population, decreasing self-sufficiency and increasing commodity prices, the annual food aid cost is rising sharply and could become an impossible burden for the United States and other donors if not reversed.

Recent and present widespread drought conditions in the United States indicate how vulnerable our own production is to periodic shortfall of requirements to adequately meet domestic needs and expanding export markets without drastic price increases to reduce demand.

Current efforts to reexamine our foreign aid commitments are both timely and appropriate. Because the use of American science and technology is so heavily interwoven with the whole foreign assistance program, this paper will examine and make recommendations on changes in the foreign assistance program that go beyond the purely research aspects.

The most effective use of the total American scientific capacity in food and agriculture has been hampered both by structural problems in the aid program and by undue competition for funds among government agencies, universities and the private sector. These problems and proposed solutions will be examined in detail in this paper.

II. The Past and Current Status of International Agricultural Development

To adequately determine how the U.S. agricultural research establishment can be used most effectively in international food and agricultural development, the past and current status helps to project future needs.

The world food and agricultural situation has changed in many respects since World War II. Initially the developing countries were part of European colonial empires that developed an extensive network of colonial agricultural officers stationed in domestic and overseas research institutes to backstop their agricultural efforts. These efforts were largely devoted to the development of plantations to raise commodities in demand in Europe and other international markets such as coffee, tea, chocolate, rubber, spices, palm oil, cononut oil, cotton, peanuts, hemp and a variety of other tropical products. Under colonial rule, most of these colonies were largely self-sufficient in food production and many of them exported some food.

Decolonization interrupted the organizational structure for agriculture and other sectors of the economies of these newly independent nations. The decolonization process was followed by major assistance programs through the various specialized agencies of the newly formed United Nations and bilateral aid programs established by the United States and the former colonial powers. This aid included massive health programs designed to eliminate smallpox, malaria and many other fatal or debilitating diseases, and to improve the nutrition of infants and childbearing women. The American Food for Peace Program and other international food aid helped alleviate starvation from climatic and other disasters. All of these efforts reduced death rates, but not birth rates. As a result, the last few decades have witnessed rapid population increases.

American food and agricultural aid during the 1950s and 1960s was dominated by efforts to build or rebuild the institutional structures for research, education, supply, storage, distribution and the other services interrupted by the process of independence. These institution-building efforts included both the use of American technicians sent overseas and large numbers of scholarships for foreign students to train in the United States. These efforts were largely of major benefit and have had a lasting impact even in countries that later underwent long periods of isolation from the western world such as Uganda, Somalia, etc.

The large food aid programs under the Food for Peace Act unfortunately were partly motivated by the large price-depressing agricultural surpluses built up by a modernized and resurgent post-war agriculture in the United States. Large amounts of very cheap food were sent to developing countries and often depressed local markets, and impeded local development of food production for crops such as wheat, corn, rice and sorghum that could be obtained more cheaply from the aid programs. The ready availability of food aid led many governments to give low priority to agriculture.

The assistance provided to the developing countries helped incomes increase and thus, per capita food consumption. With increased population growth and higher per capita food consumption, food production did not keep pace with demand in many of these countries.

Third World food production has not fared badly when compared with that of the industrial world, but recent trends are less encouraging. According to the International Food Policy Research Institute (IFPRI), for the decade starting in 1960, the low-income countries increased agricultural production by 2.3 percent, the middle-income countries by 3.6 percent, and the industrial countries by 1.5 percent. Since 1970, the average has dropped to 1.6 percent and 3.2 percent for the low- and middle-income countries and gone up to 1.8 percent for industrial countries. This trend gives a growth rate of food production considerably lower than population growth for low-income countries and barely equals growth in demand in the middle-income countries. Clearly the most serious problem lies in the poorest countries and weighs most heavily on the poorest in these countries.

The details of the current status of food and agriculture in the Third World is very well documented in "Overcoming World Hunger: The Challenge Ahead," the report of the Presidential Commission on World Hunger issued in March 1980. Because this report so thoroughly covers the current status and makes a series of recommendations on how to alleviate the problem, the subject will not be detailed here. The rest of this report will deal with the role of research and related requirements, and examine how the U.S. scientific capacity has been used in the past and recommend changes in future approaches.

III. The Role of Research and Technology as a Primary Motive Power in Agricultural Production

The highly productive modern agriculture that has developed in North America, Europe, Japan and other industrial countries is the result of large public and private investments in agricultural research and is sustained by an increasingly sophisticated array of research and educational institutions. The basic science research and its adaptation to solve the problems of farmers has been largely a function of public sector research. The development, manufacture and sale of an increasing array of products basic to modern farming and the food industry have been largely the result of research and development activities of the private sector. These products include an array of improved crop varieties; farm implements and tools; fertilizers; pesticides and other devices for controlling insects, diseases, weeds and rodents; a wide assortment of animal health products; feed additives; and the machinery to harvest, process, store and transport the products of agriculture. Food industry research has provided an ever increasing array of food products and convenience packaging.

The United States has achieved its highly efficient agricultural sector by maximum integration of federal research facilities, federally assisted state university experiment stations that have branches in most major agricultural communities, and a highly developed system of industrial research and development. The results of this research reach the farmer and other consumers by close working relationships between the sales and development staffs of the private sector and a federal/state cooperative extension education network reaching into every community which is administered by the Land-Grant universities in each state. In most other countries, there is some type of similar network, but often does not include universities.

Perhaps one of the most serious mistakes made by initial U.S. aid efforts was the belief that the technology developed through substantial investment in research by this network could be transferred directly to developing countries. This belief was widespresd in the United States, was shared by many other donors and widely accepted by developing countries. It assumed we had adequate technology to modernize and transform the productivity of food and agriculture in the largely tropical countries of the Third World. All that was needed was the technical help and adequate local extension education to bring about the same agricultural productivity and improved food consumption enjoyed in North America, Europe and other temperate zone agricultural countries.

It soon became apparent that much of the temperate zone technology was not appropriate for the tropics without major modification. In addition, there were economic, social, cultural and institutional barriers that hindered agricultural modernization even when appropriate technology was available. The transfer of the U.S.-type research and extension network also proved difficult or impossible because of longstanding local organizational patterns and tradition. Most universities were modeled after those of the colonial powers and limited their activity to academic studies and teaching and thus were not suited to the land-grant approach. The research was long established as part of the Ministries of Agriculture and their experiment stations were often located far from the universities. The extension education services were either under a separate unit of the Ministry of Agriculture or in the Ministry of Education. It has therefore taken some time to recognize the need for adequate local research and find ways of utilizing local institutional structures that differed from those in the United States. Unfortunately, the initial effort to transplant American technology caused too much emphasis on extension activities only, and retarded the development of adequate local research institutions until more recently.

Although some of the extension efforts of federal and private aid agencies were not as successful as desired, many of these were part of the broader institution building programs of the 1940s, 1950s, and early 1960s that have had significant long-terms impact. The development of universities, experiment stations and extension services manned by carefully selected local personnel who were provided scholarships to study in the United States has resulted in an improved network of developing country institutions. For example, local universities in many countries are increasingly able to provide at least the basic baccalaureate level degrees and lower level certificate programs to supply most of the demand for professionally trained staff to perpetuate the development process. There are several examples of the research and extension institutions even surviving long periods of neglect under unfriendly governments and emerging more or less intact with a staff of dedicated U.S.-trained scientists and educators ready to once again move forward. Recent examples can be found in countries like Somalia, Peru, Chile and even to some extent in Uganda.

The large investment in sending U.S. expertise from the USDA, the American universities and the private sector to help build these overseas institutions and train large numbers of foreign students in American institutions had the added advantage of developing a large corps of American scientists and teachers with firsthand knowledge or interest in international agricultural development. Unfortunately, more recent shifts away from these types of aid programs are tending to diminish this pool because of rapid retirement in relation to new additions.

The international community was slow to recognize research needs; however, the 1960s and 1970s brought increasing realization at the professional level that agricultural development was dependent on new discovery or modification of technology to make it appropriate for conditions in the tropics. Also, introduced technology needed further adaptation for local areas. These needs were much like those required to modernize temperate zone agriculture the past few decades.

This realization led to new initiatives, particularly by the Rockefeller Foundation, later joined by the Ford Foundation and then by various multilateral and bilateral donors. The Rockefeller Foundation established a Maize (corn) and Wheat Research program in Mexico in 1943 which led to new wheat varieties developed by Dr. Norman Borlaug in the 1950s. These were widely tested in the near and Middle East countries in the 1960s. They were introduced to India and Pakistan in 1963. Their impact in these various areas was dubbed "The Green Revolution," and resulted in a Nobel prize for Dr. Borlaug. The Mexican wheat and corn research program was regionalized and later internationalized to become the International Center for Wheat and Corn Research (CIMMYT) in 1966. In 1959, an International Rice Research Center in the Philippines was jointly planned by the Rockefeller and Ford Foundations and established in 1962. These initial centers founded by the two foundations were, along with two other already planned for Colombia and Nigeria, later taken over and expanded into a network of international centers sponsored by a donor group brought together with the help of the foundations. The World Bank, United Nations Development Programme (UNDP), and the Food and Agriculture Organization of the United Nations (FAO) sponsored this donor group. The donor group is known as the Consultative Group on International Agricultural Research (CGIAR). The secretariat plus a technical advisory committee that establishes research priorities and recommendations is administered on behalf of the donors by the World Bank and FAO. This effort has grown from an initial contribution of $15,000,000 for the 1972 budget of the four initial centers to a pledged $140,000,000 for 1981. The current network of centers and institutes is a significant factor in developing technology for the tropics and helping national research institutes develop and refine this technology for local use.

The United States has played a very significant, but relatively passive role in this effort. It originally pledged to provide 25 percent of the core budget of these centers. The U.S. contribution has escalated rapidly, due to the overall increase in donor pledges. In spite of their importance, the United States to date has made only limited government effort to link its scientific community to these centers or build major linkages that will insure that new technology discovered by these centers which is useful to the United States will be rapidly transferred from these centers to the mainstream of U.S. science.

The international community has also been relatively slow in recognizing the importance of developing national research capabilities. Early initiatives in this area were taken by the Agency for International Development (AID) through national program reviews in Korea, Pakistan, Bangladesh and other countries in 1966-1967. The Agricultural Development Council, a private organization, established the Malaysia Agricultural Research and Development Institute (MARDI) in 1969, and in 1971 sponsored a workshop on developing agricultural research systems in Asia. In 1967, AID proposed to a special meeting of the Development Assistance Committee of the Organization for Economic Cooperation and Development (OECD) that it support a network of national research centers in developing countries. The European members did not endorse this initiative and it died as a result.

There is current recognition by the international community that more adequate development of the national research capabilities is urgently needed. Many of them are not well enough developed to fully utilize the growing body of tropical agricultural technology. The CGIAR and the Rockefeller Foundation have both recently set up new organizations to assist and promote this effort. In addition, the collaborative research program under Title XII of the Foreign Assistance Act is starting to link American universities into this effort and to some extent start linkages with the international centers of CGIAR. For several years, an increasing number of AID contracts have been directed toward developing the research capacities in individual countries. The World Bank has provided substantial support for initiatives by the governments themselves.

The area that has been addressed least so far is how the more basic type of science research of which the United States has by far the greatest capacity and performance record can be utilized for international agricultural development. Neither the international centers nor the national institutions in the developing countries are equipped or financed to make this contribution.

The U. S. scientific community under the leadership of the National Academy of Sciences has developed a comprehensive assessment of the needs and the specific areas where American science can make the most contribution. These are detailed at great length in a series of publications that resulted from the NAS "World Food and Nutrition Study," published in 1977. The missing link in adequate use of U.S. science has been funding and organizational structure. The NAS report has recommended a $120,000,000 increase over five years for this purpose. The Carter Administration endorsed a Brookings Institute proposal based on various earlier committee reports that recommended the establishment of the "Institute for Scientific and Technological Cooperation" (ISTC) for this purpose. This did not find a favorable reaction in the Congress which authorized a more limited approach as part of AID without the funds requested.

Another U.S. limitation to adequately use its scientific capacity has been its severe limitation on expertise in tropical agriculture. The basic problems of developing a sustained and productive agriculture in the fragile environment of the tropics requires the solution of very complex problems that are quite different to those of the temperate zone. The tropical soils tend to be highly errodible, lack waterholding capacity, do not retain plant nutrients, contain many toxic metals, are subject to torrential rains often followed by periods of drought, and have a year-round climate favorable to the buildup of plant and animal pests and diseases.

In order to overcome the U.S. deficiency in tropical agricultural expertise, the U.S. Congress passed the Dole/Matsunaga amendment to the Food for Peace Act of 1966 (Sec. 406 of Public Law 89-808). This authorized up to $33,000,000 per year to build U.S. tropical agricultural capability to be shared with friendly foreign nations. The administration of this Act was assigned to USDA. Because USDA saw its involvement in international agricultural development as a conflict of interest with its responsibility to U.S. agriculture, funding for Section 406 was not requested and it was not funded at all until 1975 at which time $500,000 was appropriated through the efforts of the Hawaii Congressional delegation. This has been increased since that time to $2,800,000 for FY 80.

The majority of U.S. tropical agricultural programs reside in the University of Hawaii and associated USDA programs, in a few southern states, primarily Florida, and the USDA and university programs in Puerto Rico. The implementation of Section 406 has been directed toward expanding U.S. tropical agricultural capacity by linking various USDA and university interests and capabilities into programs developed through the establishment of two centers: the Pacific Basin Center focused around Hawaii, and the Caribbean Basin Center focused around Florida, Puerto Rico and the Virgin Islands. Limited funding and failure to give high enough program priority has caused the development of a significant and cohesive program to languish. Until recently, all funds were appropriated through the efforts of the Congressional delegations of states participating in Section 406. This has resulted in frequent disagreements between the universities and USDA on how the program should be developed, managed and funds allocated.

IV. Examination of Past and Current Instruments for the Use of U.S. Science and Technology in International Food and Agricultural Development

Agency for International Development (AID)

AID and its predecessor agencies were set up to represent the U.S. government in international development programs, including agriculture. In discharging this responsibility, AID has been the frequent recipient of criticism, both just and unjust. In the beginning of the U.S. aid efforts under the Point Four "Truman Doctrine," there was a period of close collaboration between USDA, the university community and a rapidly recruited corps of professional agriculturists that formed a substantial direct-hire professional capability in the agency. These professionals formed both a country mission level capability and provided specialized expertise based in Washington, D.C. They served either on a regional or global basis. Because most of these professionals were newly hired out of universities or USDA, this helped in the development of a spirit of teamwork between these organizations.

The developing countries were faced with the urgent need to replace colonial officers that had staffed the local government institutions and the plantations that were the only major potential source of hard currency. The use of U.S. agricultural specialists from AID, universities, USDA and private sector contractors were all welcomed as an emergency measure to man these institutions while large numbers of local staff were sent to the United States and elsewhere for training.

These institution building and training efforts were supplemented with efforts to develop improved infrastructures such as roads, power, water, schools, etc. Seeds, pesticides, fertilizer and food were provided by grants, concessionary sales or loans.

These efforts were very successful in helping the developing countries make the transition to independence. Many of them were able to take off from their early post-war status to become relatively industrialized nations. These have been designated as "aid graduate countries." This means they no longer receive aid from AID, but are expected to utilize the various international organizations and commercial loan sources available to them to maintain their development pace. These include such countries as Mexico, Brazil, Taiwan, Korea, Malaysia, Turkey, Israel, etc.

The aid effort started with the high hopes of duplicating for all developing countries the enormous success of the Marshall Plan and related programs that restored Europe and Japan. In spite of many successful programs, these over-expectations were marred by various failures, slow progress or limited success. This started a long process of reassessment that is still underway even today.

In this process many lessons have been learned and there is now adequate understanding of the problems and their solutions. Unfortunately, it has been difficult to shift the focus, reorient the direction and utilize the acquired knowledge and experience in an effective manner to help those more needy countries that failed to reach "graduate status."

The major difference between rebuilding Europe and Japan and modernizing the Third World countries lies in the fact Europe and Japan had developed the industries, education, employment skills, infrastructure and institutions required of an industrial society. Any cultural or socio-economic barriers had long before been eliminated. All that was needed was the capital to rebuild the destruction wrought by the war. Because the rebuilding created more modern facilities than those destroyed, the productive capacity was often more efficient than those in England and the United States that did not suffer the same destruction. This is still creating competitive problems for the U.S. and British industry.

AID Supported Research at the Country Level

AID support of research and related programs has not been consistent. By far the largest expenditure has been at the country mission level in response to requests by host governments. Even so, there has often been reluctance to fund research because most USAID country mission administrative personnel have not had agricultural backgrounds. They tend to think all the answers needed are available from U.S. agriculture. Projects with more rapid payoff tend to be favored in order to show concrete results during their tour of duty. This is unfortunate, because of all the donors AID usually has the best access to information in host countries, a greater chance to impact on local priorities and the largest reservoir of food and agricultural expertise available to it. The USAID missions can readily work with most donors informally to insure balanced programs with realistic objectives.

Projects at the country mission level have usually been aimed at building or strengthening the research capacity of local research institutions. Such programs have usually been carried out through contracts with universities, interagency (PASA) agreements with USDA, or sometimes through private contractors. Increasingly these activities have required close coordination with other bilateral and multilateral donors that may be supporting different aspects of the same institution. The effectiveness of these projects has been hampered by lack of qualified persons in the field missions, compounded by frequent transfers. This has made it difficult for AID to effectively serve the needs of the host countries. In addition, lengthy review and contracting procedures have made timely assistance difficult.

At the Washington, D.C. level, AID support for this research has long been handicapped by inadequate or inapporpriate staffing. Use of foreign service officers as project monitors between foreign service assignments has led to rapid turnover of administrative staff resulting in delays and mismanagement. Suspicious of research as lacking impact and relevance by some regional bureau staff prevent competent planning and implementation. There has also been a chronic lack of adequate project evaluations during and after the contract period.

AID Centrally Funded Research

This covers the various research activities that are not country-specific. Many of the research contracts funded are strictly research in nature. Others have a technical assistance component, to provide educational and other activities to hasten utilization of the research results.

Because AID does not have a research staff of its own, all centrally funded research has been contracted primarily to universities, consortia of universities, USDA, other federal agencies or in a few cases, to private research organizations. This research has included 211 d grants that as a result of insistence by the university community have been contracted to universities with minimum restrictions on their use. Their purpose is to strengthen research capability in areas where AID anticipates continuing requests for assistance and current capacity is inadequate to respond. Areas of this type have included such things as tropical soils, biological nitrogen fixation, semi-arid agriculture, livestock production in the tropics, etc. These strengthening programs usually occur over a five-year period with the intention to be followed by various mission and technical assistance contracts to utilize the expertise developed.

Other contracts have been aimed at the solution of specific problems of multi-country importance such as specific pest and disease problems, biological nitrogen fixation by tropical legumes, control of major weed problems, etc. In addition, these research activities have been used to backstop specific problems identified by USAID country missions.

Perhaps the greatest research accomplishment occurred fortuitously as a result of a decision nearly ten years ago to contribute 25 percent of the core budget of the international centers financed by pledges to the CGIAR. At its initiation, all donor pledges were only $15,000,000 while the U.S. share alone was almost $35,000,000 in 1980. Because this has been essentially pass-through funding, it has required very limited backstopping. The centers have played an increasing role in solving the problems of tropical agriculture. However, now that they are well established and functioning, the same degree of effort is needed to develop the quality of national research networks.

Title XII of the Foreign Assistance Act of 1975

Title XII was passed by the Congress in close consultation with the university community in an effort to more fully utilize the American expertise in agriculture found within universities. The Congressional sponsors of Title XII proposed to the Secretary of Agriculture that this program be made a part of USDA. When this proposal was rejected, they incorporated the program within AID without separate funding. The legislation was viewed among some AID staff as an attempt by the universities to take over part of the AID functions. This resulted in a long period of struggle between AID and the Board for International Food and Agricultural

Development (BIFAD) that was established under this legislation to oversee its implementation. BIFAD members are appointed by the President and the legislation requires that a majority are from universities and the others from outside of government. AID viewed the role of the Board as advisory to AID; however, the legislation tended to give it policy and oversight authority without AID representation on the Board. After the appointment of the first Board, the implementation of Title XII appeared to bog down in jurisdictional wrangle between BIFAD and AID. The legislation created much of the problem because Title XII did not carry new funding or provide BIFAD authority over existing funds. Thus all programs and projects identified as Title XII had to come from ongoing food and agriculture programs of AID. Without tearing down ongoing programs, new programs to be established with university participation required either a long wait for new funds or accepting ongoing programs or commitments as Title XII activities. The BIFAD was reluctant to become identified with programs in which they had not been involved in the planning and programming. Ultimately, some of both solutions have occurred, but primarily the latter. Eventually under the current process, a large segment of both country USAID mission programs and central AID programs will have had major Title XII input and will be the result of joint AID-university interaction. This process is now moving more smoothly. The long and often stormy period required to develop implementation of Title XII has caused impatience from Congress and provided ammunition to the program's critics. It has taken nearly five years for the program to become functional in nearly all of the aspects intended. There are still many unresolved problems that will be examined in more detail later.

The Title XII program has two parts; one deals with education and technical assistance at the country level, and the other deals with research. These come under two BIFAD committees established by the legislation. The Joint Committee for Agricultural Development (JCAD) deals with education and technical assistance. This committee includes representatives of the university community, AID and other federal agencies, and representatives of the private sector. Its activities are to provide greater use of U.S. agricultural capabilities in the programming and delivery of services at the country mission level. Because much of this is outside the scope of this paper, no more detail will be given.

The other part of Title XII deals with research and is under a similar committee, the Joint Research Committee (JRC). The research programs being established through this committee are called "collaborative research support programs" (CRSP). Like Title XII itself, the CRSP efforts have had a slow start, been fraught with controversy and criticism and often suspicion by various parties that they were a university grab to support their own research suffering from lack of adequate inflationary funding adjustments.

The concept of the CRSP is one of complete cooperation and collaboration in program development and conduct between the most qualified scientists in the United States, national institutions in developing countries and appropriate international agricultural research centers. Each program covers a specific area of research priority. Much of the initial delay in the program was in reaching agreement on the areas to be developed and esbablishing priorities between areas. There were also questions raised on whether these selections were being made more to fill the desires of the universities or on the basis of priorities of the recipients for which the research was intended. This was also complicated by preventing duplication of the work conducted by the network of international centers. It was also necessary to find areas of importance where the United States had adequate expertise, especially with the shortage of tropical agricultural capacity. The initial areas selected have been a mixture of commodity and disciplines. They include sorghum and millet, peanuts, small ruminants, beans and cowpeas, human nutrition, fisheries and aquaculture, pest management, and tropical soils. Root and tuber crops and post-harvest loss prevention are other categories high in future priority. A list of other areas in priority rank are to be implemented as funds permit.

It has taken time after planning grants in each area have been contracted to develop procedures that would adequately include key national and international scientists in the program development stage and insure that the appropriate U.S. expertise was identified and utilized in the process. As programs have developed it has taken additional time to develop the administrative procedures to insure smooth functioning due to the multiple U.S. universities, involved national institutes often in several different developing countries and various international centers, all part of a single research program. These problems are being resolved and the initial programs starting to function. Additional time will be needed to evaluate the effectiveness of these programs. One unique feature is that each of the participants--U.S. university, developing country and international center--involved in the program is required to contribute a significant amount of its own resources and therefore must consider the program to be of direct benefit. This is one way in which federal funds can be used to mobilize state and international funds to multiply impact. The major criticism is the high level of administrative cost required due to the cumbersome administrative structures used that includes various committees, consultants, workshops, conferences and committee meetings that use up a major portion of the total AID supplied funds.

Title XII has been promoted as providing the means for universities to commit themselves to long-term assistance in international food and agricultural development. Although many of the major universities have had multi-millions of dollars annually from AID contracts for many years, contracts have usually been approached on an ad hoc basis. This has prevented the development of career tracks, and thus promotion and tenure criteria for international activities. This has made it hazardous for younger faculty to accept assignments without jeopardy to their careers and a reluctance by administrators to release senior faculty because of the interruption it causes to ongoing programs. This has often let to the universities becoming hiring halls to fill contract obligations and thus not developing a pool of permanent faculty with international experience available for use in international programs.

The BIFAD issued a major policy paper on ways to overcome these deficiencies in the university system dated June 1980, entitled "Toward More Effective Involvement of Title XII Universities in International Agricultural Development." A companion document was adopted by the Executive Committee of NASULGC on February 13, 1979, and distributed to all member universities titled "Statement of Principles for Effective Participation of Colleges and Universities in International Development Activities." These documents are excellent reviews of the problems and potential solutions. They are taken into account in recommendations on Title XII in this paper.

CGIAR International Agricultural Research Centers Partially Funded by AID

References have already been made to these international research centers orginally started by the Rockefeller and Ford Foundations and later taken over and expanded by the CGIAR. Their funding has been discussed under "Centrally Funded Research." They are set out in this separate section for emphasis because they are a multi-donor effort. The two original centers established by the foundations were commodity-oriented, CIMMYT for wheat and corn, and IRRI for rice. The additional centers were predominantly cropping systems or geographically oriented except for CIP, which deals with potatoes. These include IITA and CIAT dealing with crops of the humid tropics of Africa and Latin America; ICRISAT dealing with the semi-arid tropics; ICARDA dealing with agriculture in the Middle East; ILRAD dealing with African livestock diseases; ILCA dealing with livestock production in Africa; the International Program on Genetic Resources dealing with germplasm preservation; IFPRI dealing with food policy research and the latest addition, ISNAR, dealing with support of national centers to help them develop their capability of utilizing and adapting research results for local use. In addition, several organizations with multiple donor contributions from among CGIAR members have been given affiliate roles. These include ICIPE dealing with insect physiology and ecology; IFC dealing with fertilizer research; AVRDC dealing with vegetable research; ICLARM dealing with fish and other living aquatic resources; and INTSOY dealing with soybeans. Several of the cropping systems or geographic centers also act as commodity leaders for specific crops important in their region or system.

Some of the key features of these centers have been their relatively adequate funding, which has permitted the construction and equipping of the finest of modern agricultural research facilities, adequate salary to attract and retain the highest quality scientists from throughout the world and an interdisciplinary team approach to most effectively utilize diverse skills. They have also developed highly effective short and longer term training programs for scientists from national institutions. They have launched outreach programs to national institutions. They have also maintained adequate travel and operating budgets and minimal bureaucratic restrictions. This combination has led to rapid progress. Center developments are in the mainstream of international agricultural research and quickly become well known and utilized in national research programs.

The regular core programs of these centers have been increasingly supplemented by special grants and projects funded by individual donors. Undoubtedly, discovery will increasingly flow from these highly effective centers back to the research organizations in the developed industrial sponsors as well as to the developing country research organizations. It is therefore imperative that the United States build adequate linkages between its scientific establishment and the CGIAR network.

The high degree of success of this network of centers in solving problems in tropical agriculture has caused many of their sponsoring donors to request their expanded use in outreach programs to support national programs. This has caused concern that if this direction is followed, they may over-extend their activities to the point that none of their activities will be done well. A compromise has been the establishment of the Institute for Support of National Agricultural Research (ISNAR) as a separate organization for this purpose.

Initially the centers tended to work on developing finished technology such as new varieties, and the package of technology needed for their successful introduction. As national institutes are developing their capacity and the centers' capability of giving them help has increased, they are moving more towards developing the basic aspects of new technology and providing it to national institutions. They have helped them complete the development of technology to suit local conditions.

In line with the more recent general international emphasis on helping the poorest of the poor, the centers have increased their efforts to develop technology that requires the least energy and cash input to improve productivity so it will be within the reach of the limited resource small farmer. This is helping to overcome early criticism that the initial output of the centers were capital-intensive and thus primarily benefitted the large, more affluent farmers, which, in turn, further handicapped the limited-resource small farmer.

The United States Department of Agriculture (USDA)

The USDA, since its early history, interpreted the Organic Act of 1862 as limiting its role to the service of U.S. agriculture. Many dedicated employees have, however, contributed significantly to foreign assistance programs under interagency personnel agreements (PASA) to carry out AID programs under pass-through funding. This often involves personal sacrifice, including jeopardy to promotion and retention of career assignments, and thus career development. Because these PASA agreements are not part of the regular agency budget, they are and have always been approached on an ad hoc basis. This is in spite of the relatively large size of this funding on an annual basis. Because there is no continuing agency funding base, there has never been a career track established for international research and development, and thus it has not been possible to develop a current pool of experienced international staff. Because these assignments are disruptive to regular ongoing programs, USDA administrators are reluctant to authorize qualified staff to take PASA assignments. As a result, USDA employees are often hesitant to go overseas because of the career penalties that may result. As a consequence, USDA, under PASA agreements, has tended to become a hiring hall for AID to find needed expertise from the outside, often on short notice. The PASA agreement has been popular with AID because of the rapidity of implementation in contrast to lengthy contract procedures required with universities and private contractors. The end result is that in the U.S. government, AID has the money and USDA has the predominant expertise. USDA does not use its expertise in the planning and program development stage of AID programs and USDA is reluctant to release its experts for implementation. As a result, USDA has a limited pool of talent with overseas experience and no career staff for continuity.

The lack of USDA direct invovlement in foreign assistance is the result of deliberate past administrative decisions by Secretaries of Agriculture. They felt this to be a conflict of interest with promoting domestic production and trade. An example was the proposal by the authors of the Title XII Amendment to the Foreign Assistance Act of 1975 to place it under the jurisdiction of USDA. Because this did not find favor with USDA administration, it was placed in AID. USDA did favor the Food for Peace Act which authorized concessionary sales of surplus U.S. agricultural commodities because it helped strengthen the price of U.S. commodities by eliminating surpluses.

Many of the lower level USDA administrators have tried unsuccessfully to strengthen the USDA role in foreign assistance. These have included detailed recommendations for implementing Section 406 (tropic and subtropic agricultural research), involvement in Title XII, and support of other international programs including the International Agricultural Research Centers, etc. These efforts were never favored in the USDA budget decision process until very recently. Some of the specific programs will be discussed in more detail. In spite of the difficulties outlined, USDA staff have made significant contributions.

For many years, USDA had a very small international program staff, but during the Carter Administration, the various international programs have been consolidated under a new Office of International Cooperation and Development (OICD) reporting to an Undersecretary of Agriculture. This has led to an international program advocacy group in USDA that could interact at the final budget decision level.

Research Authorized under PL 480

Public Law 480 permitted the sale of surplus American commodities to various friendly developing countries with payment in local currencies. This currency was used to pay local expenses of the American embassy and other U.S. government operations. A number of countries such as India, Pakistan and Egypt were provided such large quantities of food grains that the United States accumulated huge reserves of local currency. Authorization was therefore given for some of this blocked currency to be used to support approved projects carried out by the local government. Out of this evolved a wide range of agricultural research projects submitted by local scientists or based on projects of special benefit to the United States. These often took the limited local scientific capacity away from solving the urgent problems of local farmers. The role of USDA was project review, approval and oversight. The limited resources allocated to USDA for these functions did not permit major assistance in project design, technical assistance in the conduct of research, evaluation of its usefulness or assistance in its utilization.

Section 406 of Public Law 89-808: Tropical and Subtropical Agricultural Research

This amendment to the Food for Peace Act of 1966 provided authorization for research, farmer-to-farmer exchanges, and other educational programs in tropical and subtropical agriculture. This was to develop new products, technology, etc., through strengthened research and training by USDA and through contracts with appropriate American universities. The results of this research were to be shared with friendly foreign countries through farmer-to-farmer exchange programs and other means specified or permitted. Section 406 authorized expenditures of up to $33,000,000 annually for this purpose. This legislation was initially ignored by USDA in the budget process. After some pressure by the Hawaii Congressional delegation, USDA developed an implementation plan during 1971-1972. This called for the establishment of two tropical and subtropical agricultural research centers. One would be developed in Hawaii under a contract with the University of Hawaii and the other would utilize USDA facilities in Puerto Rico. These and subsequent documents proposed program priorities for research by these centers. These centers were to form a focal point for research conducted collaboratively by scientists in both USDA and landgrant universities interested or experienced in tropical agriculture. Similar details were never developed for implementing the educational authorizations. Initial funding was requested by USDA staff, but did not make it through the USDA budget process until FY 1974. An appropriation that year was recommended and passed, but was impounded and never released. Initial implementation did not occur until 1975 when $500,000 was appropriated and allocated between projects in USDA and through contracts with various universities in the southern states, Hawaii and California. This funding was increased to cover inflation costs in FY 1977. In 1978, USDA reduced its request to $400,000 to cover the amount of its own in-house research the previous year. This request was increased by the Congress to $1,800,000 as a result of efforts by the universities in Hawaii, Florida, etc. This resulted in a series of meetings between USDA and the universities of Hawaii, Florida and Puerto Rico that led to establishment of procedures for implementing the two centers originally proposed by USDA in the early 1970s. These were designated as the Pacific Basin Center for Tropical and Subtropical Agricultural Research centered in Hawaii, and the Caribbean Basin Center for Tropical and Subtropical Agricultural Research utilizing university and USDA facilities in Florida, Puerto Rico and the Virgin Islands. An administrative committee for each center was appointed along with a national committee for tropical and subtropical agricultural research. Funding was increased to $2,200,000 in FY 1979 through action of the Congress and to $2,800,000 in FY 1980. USDA finally decided to change its request for Section 406 funds from the supplementary budget category to continuing budget in FY 1981 with level funding. USDA assigned administrative responsibility for Section 406 to Federal Research (FR) under the Science and Education Administration (SEA). Competition between universities and FR scientists for the limited funding has at times hampered sound program development. It is currently being conducted more as a competitive grants program than as a cohesive program to establish overall tropical research priorities and utilize the best scientific talents to solve critical tropical problems. Because the non-research portions of Section 406 were not implemented, Congress lifted these authorizations from USDA and they are currently unassigned and thus unfunded.

Office of International Cooperation and Development (OICD)

In the USDA reorganization during the Carter Administration, various programs operated by USDA under agreements with AID and a growing number of bilateral agreements with the middle-income countries no longer eligible for AID funds were centralized under this new unit. The exception to this consolidation was administration of Section 406 which, after considerable discussion, was left in SEA. The OICD reports to a new position of Undersecretary of Agriculture for International Affairs and Commodity Programs.

Technical exchange and educational programs have been developed under a joint agreement between USDA and the National Association of State Universities and Land Grant Colleges (NASULGC). This agreement was implemented through the establishment of the "International Science and Education Council" (ISEC). This joint council struggled in its early existence because there were no funds even to cover travel costs for either USDA or NASULGC. This is now changing through an appropriation to OICD of $5,000,000 in FY 1980 to partially cover these costs and start program implementation.

Under Section 1458 of Title XIV of the Food and Agriculture Act of 1977, Congress authorized USDA to become involved in international research, extension and related technical programs in developing countries in collaboration with AID and land-grant universities, and to work directly with the more developed countries not eligible for AID support. The programs being developed in OICD through ISEC would appear to be in line with this congressional mandate as it applies to non-AID recipient countries. There does not appear to be a USDA program aimed at implementing the authorization to work with AID in developing countries. However, USDA has established some programs with AID through direct or university contracted, centrally funded research. These programs are of a non-country-specific nature such as biological nitrogen fixation. USDA has had a representative on the Joint Research Committee (JRC) of the Board for International Food and Agricultural Development (BIFAD) authorized under the Title XII amendment to the Foreign Assistance Act of 1975. This role has been more as an observer than a major participant.

The ongoing programs that became part of the OICD administration have included the PASA agreements that have provided 450 to 500 USDA scientists and technicians annually to AID throughout much of AID's existence. In addition, an AID funded, USDA administrated Foreign Training Program has annually handled short- and long-term training for about 2,000 participants from developing countries.

The newer programs of technical cooperation implemented through agreements with non-AID recipient countries now involve about twenty countries such as Spain, Israel and Brazil, with additional ones being developed for countries including Argentina, Bulgaria and the Peoples Republic of China. An agreement with the USSR is currently inactive. These are based on government-to-government agreements and actively enlist the collaborative involvement of American universities in their implementation.

Other Agency Programs

National Oceanic and Atmospheric Administration (NOAA)

This agency in the Department of Commerce has the responsibility for Sea-Grant that funds the activities of sea-grant universities. Part of these programs involve fisheries and aquaculture. There is limited sea-grant funding specifically allocated for international programs. NOAA is represented on JRC, and Title XII specifies that aquaculture/fisheries with the collaboration of NOAA will be part of the Title XII program. As a result, fisheries and aquaculture were one of the early CRSP programs funded.

National Science Foundation (NSF)

The research programs funded by NSF in the earth sciences applicable to food and agriculture have been relatively limited. In spite of the limited current direct contribution to food and agricultural research, the NSF offers a potential vehicle for linking basic science research to the solution of problems that will be of increasing importance in the future. It readily reaches the scientist in the non-agricultural universities that may have important skills to offer.

National Academy of Sciences (NAS)

The Academy has direct activities of significant relevance to this paper through its National Research Council, Board on Agriculture and Renewable Resources, and its Commission for International Programs. These NAS components are utilized by various government agencies and professional groups for establishing baseline information, appraisal studies on the status of knowledge about special issues and to define problems and develop conceptual schemes that may shape the approaches of public agencies or policies.

There have also been recent proposals and discussions between AID and NAS that would put NAS in the role of evaluating research program options and approaches and maybe even performance.

NAS has also been very effective in special studies on the state of knowledge of neglected plants, technologies and animals important to developing countries for energy, food and agriculture. Many of these studies have had significant impact such as those on neglected tropical legumes, tropical trees for firewood and building materials, unexploited plants for nutrition at the village level, the water buffalo, Banteng cattle, crocodiles and other topics. Many of these have led to significant new research efforts with major payoff in new technology or adoption. These have been heavily directed toward the tropics.

Private Sector Activities

In domestic food and agriculture, the private sector plays a major role, particularly in developmental research. This includes development of production, processing and storage equipment and structures; discovery and development of new pesticides and other pest control agents; animal health care products; animal and plant nutrients, feeds and supplements; new varieties of crops such as hybrid corn, sorghum, vegetables, etc.; new food processes, products and fortification practices for improved nutrition. This is only a partial list of private sector research which in aggregate is estimated to represent at least 25 percent of all U.S. agricultural research expenditures. Because these figures are harder to establish with accuracy than public expenditures, they may be substantially underestimated.

During the post-war period, an increasing portion of agricultural research, development and extension education has been taken over by private sector activity. Increasingly the universities' extension programs deal with the private sector field and sales representatives because they are the farmers' most frequent contact. The extension staff help by providing unbiased evaluations for the farmer to insure the reliability of private sector information.

If the private sector is so important to U.S. agriculture, why can't it be harnessed more effectively for international agricultural development? There is no simple answer to this question as the reasons are varied. An effort will be made to examine the most important.

One of the most important factors is the very size, stability and corporate experience in the local market. The United States consumes most of the world hybrid seed corn, nearly half of the world pesticide productions, and is the largest single consumer of fertilizer, machinery, animal health products, etc. By far the largest part of the remaining market for these products is in the other temperate zone, hard currency, industrial countries of Europe, Japan, Australia, etc. Why should they devote energies to the developing world, largely in the tropics, where their current products often don't work well, where small farms predominate, where local infrastructure is inadequate, where governments are not stable, where illegal payments are a standard procedure and currencies are difficult to convert and repatriate? The reason is that the future market potential is enormous. If this market were ever fully developed, it would dwarf the domestic market.

With this background, why is it that the European and Japanese private sectors have been so much more aggressive in developing or modifying technology for the developing country market? The answer lies in their relatively restricted domestic market, a history of trade as a way of life and the variety of government incentives used for this purpose. What are these incentives? They include complete tax exemption for expatriates while abroad, aggressive marketing assistance as part of diplomatic initiatives, acceptance of the need for illegal payments to gain business and allowance for them as deductible business expenses. They also provide export incentives and insurance against expropriations or losses from government instability.

In contrast, even the $20,000 short-term and $25,000 long-term overseas U.S. income tax exemption has been largely voided during the past couple of years. There is unfavorable treatment of local tax payments as deductions and limitations on deduction of fringe benefits. This does not appear to recognize the preponderance of services provided to resident citizens that are not enjoyed by overseas residents. It really comes down to their taxes becoming a subsidy for the citizens back home with very few services in return. When American firms do decide to do business abroad where expatriate staff is required, they are largely turning to non-Americans to solve the tax costs that otherwise must be added to salary.

Under current amendments to the Corrupt Practices Act, illegal payments to gain business abroad is a criminal offense. Thus American firms have increasingly stayed in business by becoming sub-contractors to non-American firms that make the illegal payments.

The basic export assistance and incentives available to American firms are generally much less than to their competitors.

In addition, the imposition of special environmental protection restrictions on some products often makes the development of new products for overseas markets impossible. Pesticides are the classic example. In order to "prevent the poisoning of people and the environment in innocent developing countries," the environmental lobby obtained restrictions that require that only pesticides can be exported that have been labeled for the same use in the United States. Because of the tropical climate in most developing countries, most of their pests, diseases and crops are different than those found in the United States. How many companies register pesticides in the United States for control of pests on rubber, palm oil, tea, cocoa, coffee, bananas, cassava, etc.? Even the pest in crops also grown in the United States tend to differ.

With all these impediments, it is amazing that American industry does even the limited research directed at overseas markets in developing countries that it does.

V. Evaluation of Alternatives for More Effective Use and Funding of U.S. Science and Technology for International Agricultural Development

The U.S. foreign assistance program has been fraught with dissatisfaction expressed in various public quarters and reflected back to the Congress throughout much of its history. The use of American science and technology in support of AID research has often been viewed very critically. As previously pointed out, much of this has resulted from an over-estimation of the value and transferability of American technology to developing countries. This has been further compounded by the typical American action and immediate result orientation. Administrators tend to have short assignment spans and thus demonstrable results in a short time become an imperative. The same pressures are on the Congress. Foreign aid does not have an instant organized constituency like many other programs. In addition, the administrative structure of AID has made it an appealing pawn in international diplomacy. Funds shift from critical area to new trouble spot, as part of foreign policy, i.e., Southeast Asia to the Middle East, for example.

Research requires long lead time, continuity and patience, if it is to have effective payoff. On the other hand, various studies have shown returns on investment in agricultural research are high compared with other investments.[1] Studies also indicate this return on investment is even higher in developing countries.[2] Most of the scientific breakthroughs such as hybrid corn, pesticides, animal health products, etc., that were the core of the American agricultural productivity explosion after World War II resulted from research in the 1920s and 1930s. Lead time can be compressed under strong pressure and liberal funding such as the "Manhattan Project" to develop the atomic bomb or the race to put a man on the moon by NASA. In both cases, they were heavily dependent on basic research started many years before the start of these crash programs. The speed of progress was enhanced by bringing together the scientists and the engineers into an interdisciplinary research and development team. This lesson needs to be kept in mind as it relates to food and agriculture. There is danger of slowing the process if research and its utilization in development are isolated from each other.

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[1] Resource Allocations and Productivity in National and International Agricultural Research, A Seminar Report. The Agricultural Development Council, Inc. New York, N.Y., September 1975. Tables 3.1 and 3.2.

[2] Bryce, James I., and Roger E. Evenson, Agricultural Research and Extension Programs, Agricultural Development Council, Inc., New York, N.Y., 1975

The answer to the problems and malfunctions that have been outlined in this paper have been the focus of various studies over a long span of years. The controversial "Pound Report of 1972" was one of the first to explore in detail the deficiencies in the use of basic science and balanced use of the U.S. scientific resources for agricultural development. A more recent report by the Brookings Institute caused President Carter's science advisor to recommend a special White House staff be assembled to develop plans for implementation of its recommendations. This task force headed by Dr. Ralph Smuckler developed a detailed proposal for establishing an Institute for Scientific and Technological Cooperation (ISTC). Although this was strongly supported by the Carter Administration, it failed to pass the Congress and be funded in an effective form.

The fortunate aspect is that while the United States has studied and agonized over the issue of how to utilized research to solve international food and agricultural problems, the rest of the world, with major leadership from private Americans and substantial U.S. government financial help, have made major progress in establishing priorities, facilities and solving some of the most urgent problems during the past two decades. The present pressing need is to develop competent and well administered; research, extension and educational institutions in the developing countries to adapt the new information to local needs; and establish the policies, incentives and educational efforts needed to cause adoption of improved technology.

In the United States and increasingly at the international level, easy advances in food and agricultural technological development have been made. This is true even if the scientific knowledge has not yet been adopted. Further progress will be dependent on much more sophisticated, time-consuming and costly types of basic and applied research. This is where America has the lead and thus the most to contribute. The need to mobilize the U.S. scientific establishment, both at home and into new partnerships abroad, is urgent if world food production is to keep pace with demand.

After reviewing a wide variety of internal and public documents and studies on the subject of how to meet these challenges, the conclusion reached is that it will require a complete overhaul of the U.S. foreign assistance programs. This should include major changes in the way government agencies are organized and interact, and relationships with the universities and the private sector.

Although the section dealing with past and current instruments for using U.S. science and technology in international agricultural development details many of the problems, further review will help build needed background.

Because of major budget reductions and policy changes being recommended by the incoming administration, now is an appropriate time for such a review and recommendations for new directions.

The staff of the Agency for International Development have been examining the various options open to the Agency in responding to the Report of the President's Commission on World Hunger along with the Congressional authorization for ISTC as an unfunded entity within AID. There appears to be general agreement among those inside and outside AID that have studied the situation carefully that with its present organization and staffing pattern, AID cannot meet the challenge. In order to examine this conclusion, an effort will be made to summarize the details behind it. To do this adequately requires examining the current status of AID in the Food and Agricultural sector and some of the Congressional and other mandates it is struggling under at the current time.

The following quote from an internal study document gives a good starting point.

"The agency has virtually lost its sense of direction in agricultural and rural development. AID has always tended to be a General Purpose Agency, but more than any other donor, it has been oriented to helping LDC's increase their capacity to solve their own problems, through training and institutional development. Currently, under a variety of stimuli, agency efforts are being diverted in many directions. There seems to be two main causes of the lack of orientation. One is a distortion in the interpretation of the New Directions Mandate of Congress that leads a significant segment of the Agency to orient its actions to the "poorest of the poor." This orientation leads to direct impact projects at retail that have limited chance of short run impact and virtually no chance of long run residual impact. . . a second serious problem leading to a confusion of direction is the diversity of special interests related to agricultural and rural development that the agency is expected to attend--energy, forestry, employment generation, women in development, appropriate technology, among others. Most of these are important concepts, and carefully orchestrated they can be functional instruments in development activities. The trouble is that they are not orchestrated, with the result that much of the good they are designed to do and could do is negated. . . . Two conditions are essential for the elimination of hunger. Most obviously, there must be the capacity to produce food--technology, inputs, markets, infrastructure, public services, and the institutions and human resources to provide them. . . . There must also be the capacity to buy food; i.e., income. Since agriculture is the major industry in most AID client countries, the agricultural development program can address the income-employment issue along with the food production issue. . . . In implementing the strategy, AID must think in terms of decades rather than fiscal years, although benefits must be expected to start to flow within a reasonable time. . . . In AID countries, the weakness of their organizations and [illegible]e functions they perform are the factors that most limit agricultural development and are the biggest impediment in eliminating hunger. The pervasive institutional weakness, including the lack of manpower, is a problem more serious in most cases than is lack of financial resources. Many donor projects fail and many financial resources are lost because of the inadequate human-institutional resource. . . . There is little doubt that AID's comparative advantage lies in the area of human and institutional resource development. In contrast, in the field of capital transfer, AID is a small and nondescript fish in a rather big pool. AID needs to recognize that no other donor has better access to LDC problems than it does, in spite of the battering it has taken during the last decade."

These excerpts give an excellent foundation for further evaluation.

One of the major AID limitations in addressing the needs is an inadequate number of appropriately trained professional staff. An examination of the records over the past ten years show a dramatic increase in funding levels in the AID agricultural sector ($270,000,000 in 1971 to $720,000,000 in 1980). The relative share of the agricultural sector in AID-appropriated funds has gone from 19 percent to 50 percent since 1970. In addition, as already outlined, Congressional and other mandates have proliferated the type of special issues that AID is expected to address in the agricultural sector. AID's total employment level peaked in 1968. Since that time, the numbers in certain professional categories have been substantially reduced, particularly in agriculture. Between 1968 and 1976, the total number of AID's U.S. employees were reduced by 55 percent; however, during the same period agriculturists were reduced 78 percent. It appears that the reduction in professional staff has been somewhat inversely proportional to funding increases. At present, with 50 percent of the resources, the agricultural officers are 5 percent of the agencies' total personnel. There are presently 256 agricultural positions with more than 20 percent vacant. Almost 80 percent of these are assigned overseas. Most of those assigned overseas act as program generalists/administrators. Many are very senior in years of service and thus age. Although about 75 percent have advanced degrees, mostly MS, very few have had recent specialized technical experience. Almost none of them have been released for in-service professional improvement in agriculture during their careers. The lack of an agricultural career ladder and professional identification has made new recruitment and retention of qualified personnel difficult. Because such a high number of total staff have been reaching retirement age recently, the pressure for new recruitment has become more critical. Understaffing and vacancies make adequate in-service orientation and training nearly impossible.[1]

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[1] Taken from a TPCA working group internal AID document.

Partly as a result of inadequate staff for effective program identification, development and monitoring in relation to funds available, the USAID missions have tended to program large amounts of the food and agricultural resources into major grants and loans as they require much less staff time per dollar expended. Although supply of food, fertilizer, machinery and infrastructure developments such as roads, irrigation systems, etc., from loans and grants can be a very useful part of institutional and human resource development programs if carefully developed as part of an overall plan; this is obviously less and less the case. There is also the tendency of the senior administrators to be judged on how much money they can program and spend. Maximum use of loans and grants, regardless of their relative merit compared to institutional and human resource development are a much cheaper and easier way to expend funding authorizations, and funds spent are easier to count in personnel evaluation than the results of less easily measured long-term programs. This is unfortunate, because as already mentioned, the World Bank, UNDP and bilateral donors, many of which have very little agricultural expertise of their own have also greatly increased their expenditures in the food and agriculture sector. They have been providing about as much in loans and grants as the countries can absorb. Clearly the need is to develop the technology, institutions and people required to make effective use of the variety of international funds available. To do this adequately requires much more staff time than for loans and grants, and it is slow; and to be effective requries patience and continuity. The United States has by far the greatest potential in technical resources; the question is whether it has the patience and willingness to provide them along with the needed continuity.

The other major limitation on adequate AID performance is the lack of an effective organizational structure in the agricultural sector to match the level of priority indicated by the high percentage of funds allocated to this sector. As indicated by the excerpts from the internal working paper quoted, AID needs to be able to develop a clear mission and a cohesive program that incorporates the mandates and special interest areas on which it is expected to perform. As now organized, AID has decentralized responsibility for sector programs without a mechanism for coordinating the activities of the twelve or more separate units dealing with agriculture and insuring cohesive planning, analysis, programming, implementation, oversight and evaluation of the sectoral program as a whole.

The planning and programming is done at the USAID mission level in each country and some of the problems entailed in matching the best U.S. capability to country needs in this process have already been flagged. Implementation is through the regional bureaus with limited technical support available from the Technical Support Bureau. Central policy coordination and technical coordination at best occurs only by required clearance sign-off by understaffed units.

At the country level, AID Mission Directors have the key role. They rarely have any agricultural background and thirteen missions do not have a single agricultural officer. The positions in a number of the other missions are vacant.

In summary, the AID limitations are primarily inadequate and inappropriate staffing in food and agriculture, inappropriate criteria for evaluating administrators, lack of appropriate administrative structures and failure to be able to utilize American advantages in causing development of a coordinated program among bilateral and multilateral donors.

In order to correct the situation outlined, there needs to be a critical evaluation of the overall scope and role of AID. It must be recognized that when funding cuts have to be made, foreign aid is one of the least controversial areas with the general public.

Like most bureaucracies over time, AID has expanded its role under a variety of mandates until it has without question the most complete portfolio of aid programs, diversity of aid recipients and the largest total and individual country staffing of any of the bilateral donors. It also has one of the most tortuous program development and contracting procedures anywhere. This makes timely and appropriate assistance extremely difficult. It also produces top-heavy staffing in programming, contracting and other administrative functions.

It therefore would appear to be an appropriate time to reduce the overall foreign assistance mandate and concentrate on those areas of most vital importance where the United States has clear superiority in its capabilities. The areas of food and agriculture, public health, population programs and education clearly have the best public support, critical importance and U.S. capabilities. As already indicated, we have excellent capabilities for providing technical assistance, but are not an important factor in capital transfer through loan and grant programs.

Other donors already provide at least adequate funds of this type. Some of these may be necessary and desirable as part of both U.S. diplomacy and as integral parts of technical assistance programs.

With these overall observations, the rest of this section will be devoted to a proposal for total reorganization of aid programs in food and agriculture and their relationships to supporting programs. It is assumed that the basic organizational structure proposed would be part of AID, but with slight modification it could become part of USDA or an independent agency.

International Food and Agricultural Development Administration (IFADA)

The IFADA must be designed and administered to overcome the basic inability of the current foreign aid structure to launch and sustain the types of programs appropriate to U.S. capability and essential to solutions of emerging world food and agriculture problems. These can be summarized as follows:

1. The lack of a qualified career technical staff of adequate size and depth to sustain such an effort at both the central and country mission level.

2. Lack of professional competence at the decision and policy making levels in either Washington, D.C. or country missions.

3. A personnel system whose reward criteria are inappropriate for the long-term mission required.

4. Lack of an adequate career ladder sufficient to attract and maintain highly qualified professional staff.

5. Lack of central policy, planning and coordination to develop, maintain and evaluate a cohesive development strategy and implementation program.

6. Lack of in-service training and career development to keep staff up-to-date and effective.

7. Lack of direct linkage to those handling U.S. liaison with the international agencies and other bilateral donors.

8. Program and contract procedures that make timely and effective assistance nearly impossible.

9. Failure to develop a long-term sustained cooperative program with other appropriate government agencies, universities, the private sector and non-government organizations (NGO's) that permit and mandate their development of competent career staffs to insure high quality contract performance.

To overcome these serious deficiencies will require a completely new organizational structure and procedures. A suggested name is the International Food and Agricultural Development Administration (IFADA).

The major weakness of such an organizational structure could be lack of cohesive program linkages with the areas of public health, education and population planning that should be an integral part of most policies, strategies and in many cases, programs. Even at worst, this would be as good as the present system in this respect.

In order to minimize these cross-sectoral problems, the general outline for IFADA will assume it is established under AID, and other structural changes in AID are recommended to enhance integration. To do this, it is proposed that AID establish the position of Deputy Administrator for Technical Assistance Programs (DATAP). The primary duty of this position would be to oversee central policy, planning, coordination and evaluation of programs in food and agriculture, public health, education and population planning. At the country USAID mission level, a new position of Deputy AID Mission Director for Technical Assistance would be established. These would be career appointments of technical specialists drawn from the technical staffs in food and agriculture, public health or education. They would report administratively to the Mission Director but would be responsible to the Deputy Administrator for Technical

Assistance for all technical matters. In the case of food and agriculture, this would be through the Director of IFADA.

IFADA should be given responsibility for all food and agricultural development in both the developing and graduate countries. The programming would be different, but responsibility the same because of the lack of USAID missions in the graduate countries.

The director of IFADA should have responsibility for all cooperative programs with USDA, other government agencies, universities, the private sector and non-government organizations dealing in food and agriculture. This should include all loan and grant funds utilized in this sector. In addition, a linkage staff should be set up to deal with all technical matters in the international agencies, CGIAR and bilateral donors in this sector of responsibility. They should be charged with developing the maximum donor coordination feasible at both the international and country levels.

To streamline the current tortuous system of programming, it is proposed that both BIFAD and the AID Research Advisory Committee (RAC) and related advisory committees be replaced by a single Advisory Committee to the Director of IFADA. Such a committee should adequately represent the interests of government agencies, universities, the private sector and NGO's This Advisory Committee could appoint special standing and ad hoc committees as necessary.

In order to implement this proposal it is recommended that a task force be established to develop the organizational and implementation details. This task force should include representatives on the Advisory Committee to the Director of IFADA.

Major reductions in the overall scope of AID and streamlining of the program, contract and administrative structure should more than free adequate positions to accommodate a reasonable staffing authorization for IFADA. If the IFADA staffing requirements cannot be met rapidly enough through hiring freezes in AID, then a reduction in forces through speeded up reductions in other programs should be implemented.

IFADA would need to have a strong base with adequate authority to establish overall policy, develop long-term goals and long- and short-term programs with clearly defined objectives.

Various central functions need to be created under the DATAP and brought together as effective support units. Central data and analytical services need to become a strong unit if AID is to be a major factor in analysis of research and development needs. This is basic to the development of cohesive programs that address the various supporting issues. These include the employment sector, appropriate technology for limited resource farmers, energy for and from agriculture, the role of women in rural development and the need to bring together the rural health and nutrition programs so that labor efficiency can be increased and infant mortality reduced through developing needed sanitation, disease and parasite reduction programs. These are basic to any sustained impact from improved nutrition.

Much of the low productivity problem is tied to inadequate energy for sustained effort by the work force in rural areas that are sapped by ecto-parasites, gastro-intestinal diseases and internal parasites that must be treated before improved nutrition can be used to provide adequate energy. Community sanitation and health education are basic to sustained reduction of these problems. Therefore, the health and nutrition programs should be programmed as a single effort and intimately tied to the production and income programs.

In the past, nearly total emphasis was on food production. To raise income levels, this must be shifted to give a balance to forestry and cash crops, including those that may raise sensitivities at home, such as cotton and tobacco. If this proves politically impossible, certainly coffee, tea, cocoa, spices, palm oil, coconuts, rubber and the other non-domestic crops should be treated as part of the income/food interdependency.

Proper perspective and priority should be given to areas that are broader than agriculture. These will require a central program and analysis staff with an effective development analysis office to develop, maintain and utilize an adequate data base. This would need to include the ability to develop and use computer models to provide better understanding of the various options, their consequences and costs in time and money.

The information explosion has created major problems for scientists, administrators and policy staff. With the rapid development of new means for storing, retrieving and handling information, the United States is in an excellent position to become a leading resource for this purpose not only for the most effective use of its own science and program needs, but for collaboration worldwide. This should be a major support facility. AID already has the start of such a program, or it could be a collaborative effort with the National Agricultural Library.

In order to insure that the heavily U.S. financed activities of the World Bank Group, UNDP and the UN specialized agencies such as FAO and WHO are used as politically acceptable vehicles to orchestrate the development of cohesive global and country level development strategies, the U.S. Permanent Representative and other support and liaison activities must be intimately tied to the programs under the AID Deputy Administrator for Technical Assistance Programs. These representatives must be involved in and fully familiar with the U.S. technical assistance program in order to influence UN agencies' programs and their interaction with donors.

A decision would need to be made as to how coordination and impact would be insured at the field level. Field needs must be reflected back to central policy, planning, and analysis and all other backstopping programs. The present organizational structure has given the primary programming and implementing authority to the USAID missions and the regional bureaus to which they are attached. This gives the emphasis on program development to the needs of the missions first, and to the regions as a secondary focus. This strongly deemphasizes sectoral needs. The present system is best designed to couple AID resources as a part of diplomatic policy in a country and among countries in a region. Because most of the countries belong to regional organizations and most of the international agencies are organized on a regional basis, it would be difficult to completely eliminate all regional focus, just as it is necessary to provide a strong country focus through the missions.

The main way authority is determined is by the control of the funds and personnel. Because Mission Directors tend to be appointed, much like ambassadors, and thus are determined largely by the political system, there need to be ways to insure adequate technical direction at the mission level. The proposal to replace the present staffing structure with a Deputy Mission Director that would be a career officer permanently under the Deputy Administrator for Technical Assistance Programs would resolve these problems. They would come out of a career ladder in the IFADA or a parallel technical area. They would have program development and coordination responsibility in all the technical areas under the mission. They would report to the Mission Director for non-technical aspects of mission duties, but would be responsible to the Deputy Administrator for all technical matters; and would have their permanent career assignment in their technical organization. If the present personnel system is not changed, necessary adjustments would need to be made in the dual Foreign Service and Civil Service tracts now utilized in AID to make such a system functional. If the main budget line was in the IFADA, then the regional bureaus would have more of a program support and liaison role with regional organizations as their functions. They would feed into the budget allocation process that would primarily relate to mission program requests that represent individual country needs under the overall policy and development strategies.

One of the most important needs of the U.S. Food and Agricultural Assistance Program is the development of an adequate and effective corps of professionals with overseas experience in a wide array of technical fields. These range from research through rural development and extension education in each technical specialty. They need knowledge of the problems at either the country or global level. In order for this to happen, a career ladder must be established for those with this type of international interest in AID, USDA, universities and other agencies and organizations that collaborate. This needs to be strongly linked to domestic staff and institutional development needs of the national institutions in the developing countries and the international organizations. Most of the experienced American staff in agencies and universities date heavily to those that gained international experience during the heavy investment in institution building under university and other contracts during the 1950s and 1960s. Because most of those in the programs of that era were at least in mid-career, many of them have already reached retirement or are rapidly approaching that age. The same happened in AID and USDA staffing, and they are fast losing most of their experienced staff and institutional memory.

The international organizations such as World Bank, UNDP, FAO, etc., were heavily staffed by the displaced colonial agricultural officers of the colonial powers after independence of their colonies. They, too, are rapidly retiring and will leave a big void in these organizations. The original staffing authorization in most of these organizations is by nationality. This is based on the level of contribution to the budget of the organizations. The 25 percent quota for Americans has rarely been filled in any of these organizations and therefore many of the American slots were utilized by the surplus colonials or from developing countries who had trained more professionals than they could absorb. In order to encourage more Americans to join these organizations, USDA for many years had a program that permitted their employees to join these organizations for up to five years and retain their job return, pension and other benefits. Where the international organization's salary structure was lower than that of USDA, it would pay the differential. Because this often resulted in loss of professional development and advancement compared with those that never left USDA, it has had declining appeal. It has tended to be more appealing at the administrative rather than the technical levels, so has not added much technical experience to the current USDA pool.

To correct these problems will require major new initiatives, substantial changes in the contracting process and between contractors and contractees. For USDA, universities and other contractors in the private sector and non-government organizations to be most effective, they need to develop a pool of qualified staff whose career development can be enhanced or at least not penalized by participation in programs overseas of various duration. There must be clear enough identification of these career opportunities to attract students to prepare for such a career. Student demand itself will be a major stimulant to universities to develop relevant courses and experience options for those desiring careers in international food and agriculture. Not all universities can be expected to develop strong programs any more than is true in other areas of the university. However, there should be priority given to those universities that develop excellence and commitment the same as is done with NSF and various other types of competitive grants.

There could be special incentives for universities that fill the recommendations in the BIFAD and NASULGC documents already noted earlier. Among the factors covered in the BIFAD document, key elements include a salary policy that gives incentive compensation for overseas service that is adequate to be attractive in view of the dislocations of family and job assignment required. Another element is modification of the appointment, promotion, tenure and merit pay policies to adequately consider professional efforts in international agriculture. There are other important points raised, many of them similar to the Land Grant document whose key points will be reproduced. The BIFAD document also addresses AID changes that are needed to provide some of the incentives to encourage participation. The following are the nine points in the NASULGC document:

1. Evidence that the administration and faculty of the institution are committed to inter-development work.

2. Adequate internal administrative and faculty review procedures to assure that the choice of overseas project opportunities is consistent with the institution's mission, commitment and competencies.

3. Availability of requisite personnel resources to assure effective, continuous institutional involvement in chosen projects.

4. Personnel policies and practices which assure that high quality, professionally active faculty members have incentives to become involved in developmental activities.

5. Appropriate administrative practices and policies to facilitate the provision of timely logistical support and professional services for individuals and groups abroad for varying time periods and in diverse locations.

6. Concerted effort, in the planning process, to gain a full understanding of the unique cultural variations applicable to each project, provisions for adequate cultural orientation for project personnel, including language when appropriate, and due consideration of the sensitivity of individuals to cultural variations in the selection of project personnel.

7. Established procedures within the institution for seriously evaluating its international work so that projects can be monitored on a continuous basis and performance corrected promptly when necessary.

8. Deliberate and sustained effort to assure that the benefits of international development experience are integrated into both ongoing campus programs (e.g., curriculum, research, individual courses) and relationships with institutions abroad.

9. Policies and practices recognizing not only the training component needs of development projects, but also the concomitant special requirements related to matriculation, advising, programming and support services needed to provide appropriate training for foreign students, particularly participant trainees.

A major incentive recommended here which would make implementation of the BIFAD and NASULGC recommendations appealing to USDA, universities and NGO's would be block grants to those that have been historic recipients of major contracts or PASA agreements. A substantial portion of the past five-year average could be used as a base. This funding would be in the form of five-year roll forward grants for perhaps 70 percent of the previous five-year average. At the end of each year of mutually satisfactory performance, an additional year would be added based on the new five-year average. If there is not satisfaction, then termination would be given with a four-year deescalation to permit absorption or relocation of career staff. The AID would then contract for services needed from these organizations, but pay only the excess over the block grant. This should require tenure track being given to faculty or staff paid under the block grant funds.

In addition, special programs should be developed to stimulate entry of students into studies to qualify for these new career tracks made possible by the block grants. These might include providing a modified equivalent to the G. I. Bill for Peace Corps returnees that entered advanced degree work in approved international programs. One approach would be to make this a loan that would be forgiven if two years were served after graduation with international programs of U.S. government agencies on contracts or block grant career tracts in universities, international agencies or other approved organizations. Those who did not choose this route would have only half of their loan forgiven.

Another additional method would be for the United States to join the associate expert scheme of the FAO. Most of the other major donors have found this a very inexpensive way to provide new graduates with the requisite international experience needed to gain regular employment.

Special graduate thesis research programs should be developed under a scholarship program through agreements with the international and appropriate national agricultural research centers in developing countries.

Another potential is for structured intern programs with the overseas programs of AID, USDA and universities under special funding for this purpose.

There need to be greater mobility in assignments between and among government agencies, universities and international organizations. The Interagency Personnel Agreement (IPA) has been increasingly used by government agencies to obtain university staff for up to two years, but it has been used only rarely in the other direction. There has been increasing use of organized legal university consortia as a means of sharing contracts and staff. There need to be ready rotation as part of career development between government and university staff and revitalization of programs to secund staff to international agencies with enhanced or at least no career penalties. These would be excellent revitalizations and updating experiences for AID and other career overseas staff. One or two years teaching in a university would let them share their experiences while updating their technical competence. In aggregate, these would tend to restore the previous colleague relationships that existed in the predecessor agencies to AID.

The International Training Program that is administered by USDA with funds provided by AID could be broadened into a comprehensive in-service training program for international staff of all agencies and contractors in addition to serving as the placement center and operations center for short- and long-term trainees in food and agriculture. As the national LDC and the international institutions mature, there should be more exchanges between their staff and American universities and agencies. Sabbatic programs should be encouraged in both directions. These activities could be coordinated by the International Training Program. This program already contracts with various universities and agencies to conduct training programs.

Evaluation of Alternative Arrangements for the Administration of IFADA

USDA

Establishing IFADA as a part of AID would be the easiest because of the links to the existing foreign assistance system. Linkages to the other program areas recommended are in the same agency, and the central support programs could efficiently serve more than the food and agricultural sector. They would also be a primary force in establishing and maintaining cross-sectoral integration and coordination of programs. If it were felt a total departure from past agency relationships were necessary to provide the degree of change desire, then USDA would be the logical choice. In such a situation, IFADA should replace OICD. To be viable, Congress would need to give USDA a clear mandate and budget for this purpose. It also would need to structure the appropriation process so the appropriate committees would act on the IFADA budget to insure they would not be in direct competition with domestic programs in the appropriation process. The same would be required of the budget process within USDA. This could be a joint process between USDA and AID or, if not, it should be a completely separate budget decision package within USDA. There should be strong advocacy and defense at the Under-Secretary level to give it equal weight in the final budget decision process at the department level. Incorporation within USDA would also require developing operational agreements between USDA and the State Department at the country level. These could be patterned after those now utilized with respect to the Foreign Agricultural Service.

There are advantages of this approach which could help offset the disadvantages. It would force a career international agricultural track on USDA and provide it with international capability and linkages abroad of increasing importance to domestic needs. The diversity of career opportunities would be appealing to professional agriculturists compared to the more limited opportunities if kept within AID. USDA has built-in mechanisms and a long-standing history of utilizing the agricultural talents in the university system that was the intent of Title XII. These could be expanded and still be more cost-effective than the cumbersome and costly added staffing and procedures developed in AID to implement Title XII.

Other working papers of the OTA assessment of U.S. agricultural research indicate that USDA-university relationships have serious difficulties, so placing IFADA in USDA will not automatically bring effective use of their science and technology to bear on international agricultural development. It could create new competition and strained relations with universities due to the enhanced in-house capacity that would be built up within USDA. It would be anticipated that if IFADA stayed within AID there would be minimum competition between a comparatively smaller career agricultural staff and potential contracts with universities and it would not be competition between their own staff versus outside contracting as an option which would be the case if IFADA were placed in USDA.

Taking all these factors into consideration, keeping IFADA within AID is recommended as the best choice, but placing it within USDA would be a feasible alternative.

Independent Agency Status

Making IFADA either an independent agency or a quasi-independent agency as proposed by the Carter Administration for ISTIC would have limited advantages. It could create isolation from the priority needs, would either require being expanded to include linkage areas in public health, education, etc., or would require cumbersome cross-agency linkages. If all the needed support services had to be created for a new agency, it would greatly reduce cost-effectiveness. This approach is therefore not recommended.

Interagency Approach

As currently organized, AID does not have a cohesive international food and agricultural program. USDA historically hasn't had one either. What programs it has had have been largely through AID contracts and PASA agreements. Under Section 1458 of Title XIV of the Food and Agriculture Act of 1977, Congress gave USDA a sweeping new mandate to develop such programs in cooperation with AID and the university community. As already outlined, this has been implemented more organizationally than substantially. The main progress has been with non-AID recipient countries.

If the proposed responsibilities of IFADA were to be split up between agencies, then the logical split would be to leave the programs, primarily high technology, dealing with the non-aid recipient middle-income countries in USDA.

To help insure maximum efficiency and integration, it is recommended that all these programs be budgeted and administered through IFADA. If the roll forward block grant proposed for USDA funding is established, then USDA would be able to develop a cohesive international program. It would be recommended that this be done and appropriate middle-income country agreements would become programs within this block grant to USDA for administration and implementation. Separating the programming, budgeting and evaluation segments between agencies is not recommended and should remain with IFADA.

Special Recommendations Dealing with Various Ongoing Research and Technology Programs in Various Agencies

Title XII

As previously outlined, Title XII originated as an effort by the university community to insure greater participation in the international agricultural development process. The law created high expectations in the university community for substantial new funds to build an international dimension in all interested universities. They expected to receive enough funds to institutionalize their hopes.

The law provided everything needed to satisfy these hopes except for new appropriations or authority over old appropriations. This has led to disenchantment for many in the university community, AID and the Congress. For those that have received significant funding at the country program level under JCAD, it would probably have come to them anyway without the tortuous process involved. Their bonus has been an average of $100,000 per year of "strengthening grants," funds over which they can exercise major discretion in order to strengthen their basic international programs.

For those few universities that have been funded under the Cooperative Research Support Programs (CRSP) they have received funds that would normally have been available under AID centrally funded research anyway, but with much fewer strings attached and not eroded by the high administrative costs levied by the Title XII process. They also would not have the high administrative and matching fund requirements that are built into the CRSP implementation system.

It is therefore recommended that the Title XII legislation be dismantled. Those programs now contracted should be continued. The merits and shortcomings of the present CRSP contracts should be evaluated after sufficient time has elapsed. The Title XII intentions should be incorporated into the basic policies, strategies, goals, objectives and programs of IFADA as appropriate. The task force recommended to develop the details for IFADA implementation should carefully study the whole BIFAD history, accomplishments and shortcomings as part of their process. The integral harnessing of the U.S. science and technology capacity in the universities should come about by carefully setting the prerequisite criteria that universities must meet using the BIFAD and NASULGC papers already noted, to obtain and retain the privileges of the five-year roll forward block grants recommended.

Centrally Funded Research

All appropriate options should be explored on how IFADA can use the concepts developed under JRC and the proposed ISTC or other approaches such as those used by CGIAR to establish research priorities and programs efficiently and effectively. In this process, special evaluation should be made of past and ongoing programs that appear to have demonstrated major mutual benefits between the needs of various American institutions and those of developing countries. Some of these have mobilized significant state, country and international resources for mutual benefit. Many of these may have thus brought a double benefit for each dollar expended. Some suggestions would include the soybean and corn programs of the University of Illinois, the sorghum program of Purdue University and others, the wheat and weed control programs of Oregon State University, the benchmark soil and nitrogen fixation programs of the University of Hawaii, etc. Out of such a study may come the basis for institutionalizing some very highly cost-effective international research networks that could provide much more cost/return benefits than the CRSP programs.

These international research networks parallel recent uses of regional and national research coordinating committees among U.S. universities and USDA experiment stations. This involves bringing together scientists from various institutions working on interrelated or similar problems once a year to develop a coordinated research program. Each participant agrees on what their contribution will be. The next year they all meet and report their results and use them as a basis for planning the next year's program. This tends to develop acquaintanceship and friendship between scientists in widely scattered institutions. The peer pressure to look good among their colleagues helps increase both quality and quantity of productivity. The minimum cost can be only that of the annual meeting. Rotation between research sites gives periodic local recognition as an added bonus. This process is underutilized in relation to its cost/benefit ratio. The money for a single CRSP could fund a number of these networks.

So far the CRSP and AID Central Research programs have supported only mission-oriented research. This is desirable and needs expansion and added depth. It still does not provide the support needed for very basic research and its early linkage to mission-oriented projects. Those could be accomplished by expanding a USDA type competitive grant program for this purpose or setting up a special NSF program. NSF has been sympathetic to these needs, but hasn't been able to initiate programs of consequence.

Programs of this type could include research on basic processes of plants such as photosynthesis, water economies and nutrient and other metabolic and synthesis processes with the long-range objectives of finding ways of improving these basic systems through genetic engineering, plant growth regulating chemicals or other procedures in plants and animals important to the tropics.

The mechanism of gene action and understanding the potentials of genetic engineering and its limitations are other areas in this category. Understanding natural mechanisms of plant resistance to pests and diseases could improve the use of genetics or could make possible the use of genetic engineering to improve pest and disease control without the use of pesticides. For example, the most widely used, safest, fastest acting and most potent insecticide used in most household aerosol sprays is a natural extract from the pyrethrum plant that is nearly resistant to all insect attack. Could the genes that cause production of pyrethrum be transferred to other plants? What are other plant protective mechanisms?

What causes senescence of plants and animals? Is it reversible? The answer to these questions could be important in food production, but could lead to larger social and ethical issues such as human aging. A similar area with potential social questions is the possibility of ova culture in artificial media to substitute for the uterus of animals. This would make "hatchery" production of calves, lambs, etc., possible and reduce the need for large herds producing one offspring each year per female. Such research is of a basic nature needed for the next generation of agricultural technology, but it must be integrated in programs to determine its adaptive potential for tropical areas, crops and livestock.

NSF

To insure the widest scientific participation in the types of basic research for which examples were given, NSF could act as an appropriate vehicle. This would also reduce competition within a single agency between basic research and mission-oriented research. The separate use of the USDA Competitive Grants Program could substitute for NSF, but NSF may be able to involve a broader range of scientists.

NAS

The National Academy has been a center for policy and state-of-the-art assessment. Their program to examine inadequately explored areas of scientific importance has been very productive. It has been supported by AID and should be continued with at least current support. The Academy should continue to be used to examine periodically the potentials and priorities for basic research and policy, priorities and issues relating to mission-oriented research and where appropriate, evaluation of progress or examine the causes for failure of programs.

Section 406 of P.L. 89/808, Tropical and Sub-Tropical Agricultural Research

The history and funding of Section 406 has been covered in some detail previously. This section recommends future use of this authorization. The general concept of the two centers (Pacific Basin and Caribbean Basin) should be used as the bese for program development.

If the United States is serious about using its science and technology for international agricultural development, then it needs to expand the relevance of its technology by insuring that a wider pool of its talent has an understanding of the problems of the tropics.

The centers could become key elements for in-service training programs for U.S. international staff and in the training programs of students, both domestic and foreign, in problems more relevant to the tropics than can be obtained in temperate zone universities. Course work and degrees could be provided by various universities through special courses from these centers. These programs could be carried out through special summer institutes and arrangements for thesis research and some course work to be conducted in tropical programs at these centers. The core staff of the centers could constitute a pool of the most experienced U.S. experts in tropical agriculture that could be used as consultants in program development and review both at the domestic level and overseas. The centers could also serve as excellent locations for sabbatic leave programs for both domestic scientists and overseas scientists.

In the case of Hawaii, there should be major effort to link relevant activities of the East-West Center, which is an autonomous international center, predominantly U.S. financed but with limited contributions from other donors. The Resource Science Institute of the East-West Center has absorbed the various programs previously carried on for many years by the Food Institute, which was amalgamated with other programs such as energy and mineral resources to form the new institute. They have dealt most heavily with policy issues and training.

These Section 406 centers should serve both the need for improving the agriculture in tropical areas of the United States and its territories and to form a bridge to tropical research abroad. They should also function as a collection point for information on useful germ plasm and an early warning system for potentially dangerous introductions of new pests and diseases from the tropics.

The Caribbean Center can, through partnership arrangements, benefit the agriculture of Puerto Rico and the Virgin Islands. These islands can provide major research sites in return. The Hawaii Center can fill the same functions for Guam, American Samoa, the Northern Marianas and the three new nations emerging out of the U.S. Pacific Trust Territories in Micronesia.

This research has value to the tropical agriculture of the United States, acts as a point of protection from foreign pests and diseases, and a collection point for new technology from abroad with useful application in the United States. These centers can provide local benefits to various states and U.S. territories, national domestic benefit and be a key element in the use of U.S. science for international agricultural development.

USDA has until recently resisted implementation of Section 406 because the authors of the legislation were strongly interested in its international implications. USDA felt it therefore could be competitive with its domestic programs. This led to a major struggle in the Carter Administration for jurisdiction over this program. SEA, when efforts by interested universities resulted in substantial appropriation increases by the Congress, decided to give it strictly a domestic tropical agriculture focus and keep it. OICD took over all of the other international programs in SEA under the USDA reorganization and wanted Section 406 also. Because of the decision to limit it to domestic issues, SEA was allowed to keep it.

In order for the program to be adequately implemented, facilities will need to be upgraded in Hawaii, Puerto Rico and perhaps to a more limited extent in the territories. Hawaii committed $25,000,000 in state funds for this purpose, but expenditure has been slowed. As a result inflation is increasing the cost. The delay is the result of a constitutional expenditure ceiling established as an aftermath of the California Proposition 13 publicity. It is therefore recommended that Federal matching funds be provided for needed facilities where they serve national needs. They then should house both state, commonwealth or territorial programs and Federal programs and staff.

It is recommended that Congress request the comprehensive development of a detailed program and plans for facilities and for administrative arrangements and procedures at an early date. Leading scientists experienced in tropical agriculture should be brought together to help identify the future needs in tropical agriculture that can be best met by the high technology science in which the United States excels. This should form the program core for these centers. American scientists should then be provided the opportunity to put forth proposals that address the solutions to these problems and have them approved based on their relative merit.

To give an unbiased plan for these centers, a task force of competent individuals without direct involvement with USDA or the universities involved should develop detailed recommendations for the future of the 406 programs and centers.

CGIAR Sponsored International Centers

As previously discussed, this network of excellent agricultural research centers located in developing countries has evolved with minimum U.S. input other than the pledge to pay 25 percent of their core budget.

Because of its funding level, the United States should be more involved in decisions on where the centers' emphasis will be in the future. Because the centers have been so successful in solving many pressing problems and providing the motive force for utilization of their discoveries through growing outreach programs, some donors would like to see them used as the vehicle for improving national research, extension, training and other technical programs. This is partly a response to dissatisfaction with the performance of UNDP/FAO programs for this purpose. Others have resisted this pressure because they fear this would lead to creating a new FAO. The magnitude and variety of responsibility could soon result in neither the research or the new responsibilities being carried out with the quality or professional competence and productivity that now characterizes the centers. There is even fear their present size is starting to erode efficiency and responsiveness. These concerns have led the CGIAR to field an evaluation team to examine these issues during 1981.

There is general agreement that strong research, extension and training capabilities at the individual country level is the most desirable goal. The question is more the most effective route.

As the quality of the more advanced national research institutes approach that of the international centers, they should increasingly take over more of the functions originally performed by the centers. The centers are beginning to move from highly mission-oriented research to providing outreach assistance to the national institutes for this function. In the future, this should permit the centers to focus on more basic aspects of agriculture in the tropics. In order to do this, the centers are starting resident visiting scientist and intern training programs to prepare the national institute scientists for the shift in responsibility.

The question of how far the International Centers should move toward basic research over time is becoming an issue. They are torn between those who feel they should become more science-oriented and those that feel they should emphasize training and assistance to national research institutes. Therefore, the recent establishment of ISNAR as a special outreach center to explore these directions is a significant compromise. The Unites States should take an active role in these efforts to chart future direction. Because the United States also contributes 25 percent to FAO, UNDP and has the largest bilateral program, it should take more interest in crucial issues that are fundamental to how U.S. agricultural science is most effectively utilized in international agricultural development. This more active role should be a specific responsibility given to IFADA.

The Role of the Private Sector

There is urgent national need to increase the export of American goods and services to bring in the required revenue to pay for the large importation of oil. The three major components of export earnings are industrial goods such as aircraft, computers, etc.; agricultural commodities; and services. In the industrial goods sector, agricultural goods include farm machinery, processing and manufacturing machinery, storage structures, pesticides, fertilizers, animal health products, etc. Another major portion are farm commodities, particularly wheat, corn, soybeans, cotton and rice. Livestock breeding stock, baby chickens and other livestock are also of some importance. One of the fastest growing areas of American efforts are services. These include insurance, accounting, management, engineering and a wide variety of consulting services. They, in aggregate, are larger than all agricultural commodity exports. The American agribusiness sector is a rapidly growing portion of this service sector. It provides feasibility studies, engineering services, construction, supervision, evaluation, management and a wide array of services to operating agribusinesses. They are also frequent joint venture partners.

The success of all these operations--supply of machinery, pesticides, animal health products and fertilizers and the supply of American agricultural commodities and services--are all dependent on research to keep American products superior, U.S. commodities competively priced and services that provide the technical know-how and management that is relevant to the needs.

Developing adequate means of using American agricultural research capabilities at both the government and private sector levels in close partnership with the needs of developing countries is basic to insure the growth of income to American industry from sales and service and to insure the competitive position of the products of American farmers.

There has already been discussion on the restrictions that limit investment in research on products specifically designed for developing country use, and why American companies abroad are hiring primarily nationals of other countries such as Canadians, Europeans and others, and why they often arrange to be subcontractors rather than prime contractors.

A special study of these problems is recommended because they are broader than the food and agricultural sector and are beyond the scope of this paper. The areas that disadvantage American industry most are failure to provide tax relief for Americans living abroad. They have major burdens and hardships not faced by residents and receive few of the services provided to residents. Thus, they should not be taxed for the services they do not receive. Increased salary levels paid to compensate make American prices too high to be competitive.

Restrictions imposed by the Environmental Protection Agency both on domestic products and exports are often not only unduly restrictive but in some cases irrelevant as imposed on exports.

The third area is in restriction on special fees required to obtain business, custom clearances and other requisites of doing business that are now illegal under current laws. It would seem that although well intentioned, these restrictions are primarily resulting in American companies having to provide advantages to their foreign competitors. The payments are being made by foreign companies with American companies not directly involved by becoming subcontractors. The end result is the same, but American companies come out on the short end.

VI. Examination of the Current Status and Value of Interchange of New Technology between International and National Centers and U.S. Research Agencies

The United States is now going through the traumatic experience of finding that non-American technology in such areas as automobile and steel production has created near collapse of these basic American domestic industries. The lesson to be learned from this is that the world is very competitive and if America doesn't exert adequate effort to keep up, it will suffer the consequences.

At the moment, American agriculture is the envy of the whole world. Our overall productivity, based on high efficiency, is unmatched. It has been the result not only of favorable agricultural lands and climate, but also of a research and education system that so far has been unmatched. This system is based on a unique relationship between the Federal government and state universities in agricultural research and extension and between the public and private sector in research, development and sale of new products and technology.

If the United States wishes to keep this lead, it must heed the various trouble flags that are flying. For nearly a decade, the funding of public sector agricultural research, extension and education have not kept pace with inflation. At the same time, an array of regulatory restrictions have tied up the private sector research establishment increasingly in research to comply with regulations rather than for new invention.

As this has taken place, the international donor community has come together in a coordinated and cohesive program to develop a network of international agricultural research centers and tie them into a rapidly developing network of competent national research institutions.

These are being built with the most modern facilities, the latest equipment and staffed with new young vigorous scientists fresh from training in the best institutes and universities in the world. At the same time, the U.S. agricultural research establishment increasingly is housed in outdated facilities, often utilizes outmoded equipment and is heavily staffed by scientists that will soon reach their final years before retirement. If we can't reverse the slide in our own system, the least we can do is link into the international network and use to the extent possible their increasing capability and discoveries to keep our own agriculture healthy.

At the same time, we are far ahead in the use of basic science research for agricultural progress. Because we have solved the easy problems, new basic knowledge breakthroughs become increasingly important. The basic sciences have fared better than agriculture in funding increases, so we still have a commanding lead. The question is, how can we develop a sound partnership arrangements.

In order to gain the maximum efficiency from scarce domestic and international funds, there is increasing concern on how to identify the most important problems and coordinate efforts toward their solution. The CGIAR has created a Technical Advisory Committee (TAC) that has this primary function. The National Academy of Science has taken the lead role in the United States in looking at national and international priorities. A whole new committee structure mandated by Title XIV of the Food and Agriculture Act of 1977 is attempting to do this for the United States. In many cases, developing countries are establishing research priorities without the knowledge that others have already solved the problem. The information explosion has led to an equally large awareness gap. The problem not only exists at the scientists' level, but also is a factor between donors at the country level. The countries have limited resources. Their best utilization is not found through competition for them by the various donors in each country. The IFADA should address these issues as part of its basic charter.

VII. The Implications for Agriculture and Agribusiness of International Agricultural Development

Over the last few decades, support for foreign agricultural programs at both the Federal level, and in the case of universities at the state and local levels, has been mixed. The general community has had concern about the world food problems and feel the United States should do what it can to help out. On the other hand, the agricultural community has been concerned about the effect local production in the developing countries would have on them. This concern at first was centered around the large dumping of American surplus crops that provided a means of getting rid of price-depressing surplus. There was fear that if they grew their own food, they wouldn't need ours and the surplus problem would increase and prices would drop. When these surpluses disappeared in the early 1970s and prices rose sharply stimulated by rapidly growing world markets, then fear shifted to what would happen to these markets if agriculture improved in developing countries.

In the first place, most of American exports are to cash customers in Japan, China, the USSR and other Asian areas such as Hong Kong, Singapore, etc. In addition, the best developing country markets are in the emerging group of middle income countries. They also are importing a greater variety of American agricultural products, not just the basic foods such as wheat and rice.

The evidence then is that as countries develop their primarily agricultural economies, this development fuels improvement in other sectors causing incomes to rise and creates demand for a wide variety of American agricultural and non-agricultural products. Therefore, all the indications are that any help that strengthens developing country agriculture leads to larger total U.S. exports. The agricultural exports are not only greater but are of a broader nature than before.

Agricultural development creates much larger demands for American machinery, pesticides, fertilizers, consulting services, joint venture enterprises, etc. These countries have most of the world's population, vast areas of agriculture and yet consume very little of the supplies used by temperate agriculture, even though the need is greater. An example is pesticides. The Unites States consumes nearly half of all the pesticides produced in the world. All the developing countries combined use only about 10 percent of world productions. This is about the same as the very small agriculture in Japan. However, the pest problems, because of their tropical climates, are far more severe in developing countries.[1]

Therefore, the full development of agriculture in the developing world would open enormous markets for American commodities, supplies and services. Therefore, American expenditures on effective programs to use our agricultural science for international development should be treated as an investment rather than a cost as they will be returned many times over just as agricultural research in the Unites States has had a high return on investment.

There is a tendency for the United States to have an unfounded fear of the competitive ability of developing countries with the United States. This is based on the assumption their cheaper land and labor make them more competitive. The cost of production in most developing countries does not bear this out. Labor productivity is so low, and the wages quoted such a small part of the total compared with non-salary compensations provided in the average developing countries' social systems that U.S. cost per unit of output is usually considerable lower. Keeping our own technology out in front is the best insurance policy against being unable to compete. Even if competition in certain markets tip in their favor, the earnings tend to flow to the United States for other commodities, goods and services.

Many of these countries do not produce oil so increasing energy costs are hitting them hardest. This creates much higher rates of inflation than in the United States that further erodes their competitive position. It also gives greater urgency for them to increase their exports to stay solvent. Most of these are tropical commodities out of their plantations that we do not produce. Help from our technology assistance for these tropical crops may help their survival against oil price shock.

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Commissioned Paper IX

A COMPARATIVE STUDY OF NATIONAL AGRICULTURAL RESEARCH SYSTEMS IN SELECTED COUNTRIES

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Office of Technology Assessment

January 1981

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SUMMARY AND RECOMMENDATIONS

This background paper examines the national systems for agricultural research in six foreign countries--Australia, Brazil, India, Japan, West Germany and the United Kingdom. To facilitate comparison the sections on each country are organized in the same fashion.

Segments of these country reports discuss the agricultural situation, the stated agricultural objectives, and the agricultural research policy. These sections of the report attempt to provide a sense of the context within which agricultural research in a particular country must be carried out. The fertility and amount of arable land, the population and organization of farmers and the stated political aims of the country with regard to agriculture are regarded as important determinants of a research system.

For each country the organization and administration of the national agricultural research system is described. Methods of funding are discussed as are staffing and staff development where information is available. Relationships with higher education, private industry and with extension services are examined.

All of the countries examined in this paper have clearly elucidated the priorities for agriculture and most have established a successful research system. Generally, the coordination of research effort at the assigning of priorities is the responsibility of a prestigious, stable and continuing national research council. The centralization of authority has been reversed to a degree in Japan, where prefectural units have increased autonomy in recent years but in most countries the trend is in the other direction.

An interesting aspect of this comparative study is the way in which various countries have organized agricultural policy and structure to protect the environment and the social structure of rural communities. Japan and West Germany are examples of countries that have limited agricultural productivity but have structured policy to maintain small family farms where, in most cases, the farmer has other, non-farm employment.

A detailed examination of these systems is beyond the scope of this report. However, the information obtained suggests the following recommendations:

1) Other countries have developed research systems that are successful and that are significantly different from that of the United States. It is suggested that a team of experts should examine systems of interest (for example, Australia, Brazil) and arrange an on-site visit.

2) An examination is warranted of the system for determining agricultural research priorities in this country. Methods of integrating and coordinating the many research programs are desirable in a manner that is structured for the input of all parties concerned and that is beyond partisan politics.

3) Further examination should be made of the ways in which foreign agricultural systems have made accommodation to support both large and small farms to the benefit of all.

4) Careful attention should be paid to the role of scientist as manager in research units. Scientists must be involved in planning research programs and in effectively managing laboratories in order to obtain the greatest measure of effectiveness from the research personnel.

OBJECTIVES

This background paper was designed to examine national agricultural research establishments of six foreign countries. It examines the structure and management of each system, which segments of society benefit from its efforts, and which facets of its operation contribute to its success.

In examining these systems an attempt has been made to identify:

- How research priorities are determined. What is the balance between local and national goals.
- How budgetary allocations are made.
- How success is evaluated and rewarded; review processes involved.

- What is the balance between basic and applied research.

- Where agricultural research is based; experimental stations, universities, private industry.

- What kinds of scientists enter these systems. The desirability of these organizations as career locations.

- What is the interplay of public policy, science, and research and what is the role of public office, users, and scientists.

APPROACH TO THIS STUDY

It appears that there has been very little attention paid to cross-cultural examination of research systems. The only systematic study is one carried out by UNESCO which set out to develop a methodology that could broadly and accurately describe the current state of a complex R&D system and to evaluate ways in which this information can help to guide science policymakers and R&D managers toward more effective and efficient ways of organizing research and development activities. Some of the data from this study have been published (1) and UNESCO proposes to publish a methodological guidebook describing procedures for the application of the methods development by the International Research Team that examined six European countries.

The findings of the UNESCO study were

- That the R&D process is responsive to similar psychological, social, organizational and structural factors whatever the particular national setting.

- That the criteria of successful R&D performance is multi-dimensional in nature; each system is more successful in some dimensions than in others.

- That research effectiveness is closely correlated with researchers' morale and sense of involvement with the unit. This particularly relates to the competence and personality of the unit director. This fact suggests that unit effectiveness might be improved by management techniques.

As far as could be determined, this is the only cross-cultural study of R&D organizations that is available. Within the constraints of time available for this study a literature search was carried out. A search of agricultural and science libraries revealed very few references to research organizations and few references to national systems except for India. It is interesting to note that data on these systems is located exclusively in libraries concerned with policy, economics and management. These are areas in which scientists have traditionally not concerned themselves and this fact has important ramifications for the future of research systems. There has been virtually no involvement of agricultural scientists in rationalizing the planning of research. Arron (2) commented on this:

> Even where this subject has been treated, as in the case of a special symposium on resources allocation in agricultural research, no biological scientists were present. This was due, in the words of the editor of the proceedings of this seminar, to the fact that "the topics considered were primarily concerned with methodology, its results and its implications"—this being an area to which "biological scientists traditionally have not paid a great deal of interest" (Fishel, ed., 1971).
>
> It is certain that without the active participation of biological scientists (who constitute a majority of the workers in agricultural research) in the decision-making process it is not possible to plan and programme agricultural research. Such active involvement, to be effective, predicates an understanding of the necessary methodology, its applicability and limitations, even if the actual calculations can be left to the economists.

In addition to library resources, information was obtained from embassies, international agencies, the United Nations, the State Department, and from United States experts on particular countries. The unevenness of discussion on some countries reflects the variability in the literature available, particularly that in the English language.

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GLOSSARY

Australia

AAC	- Australian Agricultural Council
OECD	- Organization for Economic & Cooperative Development
ASTEC	- Australian Science & Technology Council
CSIRO	- Commonwealth Scientific Industrial Research Organization

Brazil

PRO-AGRO	- Brazil's Comprehensive Crop Insurance Program
COMPATER	- National Commission for Agricultural Research, Technical Assistance and Rural Extension
EMBRAPA	- Brazilian Agricultural Research Corporation
EMBRATER	- Brazilian Technical Assistance & Rural Extension Corporation
DNPEA	- National Department of Agricultural Research
VEPAE	- State Agricultural Experiment Station
PPBS	- Program Planning & Budgetary System
ABCAR	- Brazilian Association of Credit & Rural Technical Assistance
ACAR	- State Agricultural Association
DDT	- Department of Diffusion of Technology
DTS	- Department of Technical Support

India

ICAR	- Indian Council of Agricultural Research
AICRP	- All-India Coordinated Research Projects

Federal Republic of Germany

EEC	- European Economic Community
DFG	- German Research Association
MPG	- Max Planck Society for the Promotion of Science

United Kingdom

ARC	- Agricultural Research Council
MAFF	- Ministry of Agriculture, Fisheries & Food
JCO	- Joint Consultative Organization
DAFS	- Department of Agriculture & Fisheries for Scotland
ADAS	- Agricultural Development & Advisory Service

AUSTRALIA

Agricultural Situation

Since the establishment of Australia as an agricultural producer, rural industry has been relatively capital-intensive because labor is scarce relative to land. The farms are large and highly mechanized. Arable land is generally of poor quality; 63% of Australia's total area is covered by desert or semi-arid soils and a further 14% by skeletal soil on mountainous country.

Approximately 6% of the GNP is attributable to agriculture.

Agricultural Objectives

In the past the government has aimed to promote stability of the agricultural sector by the establishment of orderly marketing arrangements, price stabilization schemes and by governmental loans. These policies were formulated on a product-by-product basis and did not aim to provide a guaranteed minimum level of farm income. The major emphasis was toward increasing output and the export of farm products.

Recently, however, the problems of over-supply and falling demand have caused the government to alter its policies somewhat. Policy is now directed toward balancing supply against expected demand for a commodity and in assisting adjustments by those industries most affected. The government will not underwrite surplus production.

Agricultural Research Policy

The Commonwealth of Australia is a federation of seven states. Specific powers are vested in the Commonwealth Government under the Constitution.

Regarding agriculture, policy matters that affect the Commonwealth and one or more of the States are discussed by the Australian Agricultural Council (AAC). The Council is a permanent organization, formed in 1934, and is comprised of the Commonwealth Ministers for Primary Industry, Trade and Industry, Interior and External Territories, and the State Ministers of Agriculture. Its main concerns are with agricultural marketing and financial assistance. Although its role is consultative only, in practice it is the forum where national priorities are discussed and policies requiring national action and coordination are formulated.

In 1974, the OECD Examiner's Report on Science and Technology in Australia criticized the fractionalization of Australian agricultural research and development and questioned the effectiveness of the AAC in influencing coordination. The Industries Assistance Commission review of agricultural research in 1976 also pinpointed the need for coordination and for the continuing review of rural research priorities and policies.

In response to these reports in 1978 the government established a Commonwealth Council for Rural Research and Extension. This council is a part-time independent advisory committee to the Minister of Primary Industry and consists of a chairman and seven other members appointed from universities, industry and government. As ASTEC (Australian Science and Technology Council) had suggested in its report of 1977, this council

> "after discussions with representatives of producers, research organizations and extension services, (will) recommend national priorities for research and development in Australia and advise the Minister for Primary Industry whether these national priorities are being met."

Agricultural Research

Agricultural research in Australia has received financial support from both the Commonwealth and State Governments. The Commonwealth Government provides funds directly to the Commonwealth Scientific Industrial Research Organization (CSIRO). State governments directly support research through their own research stations and laboratories.

The CSIRO was established in 1926 to carry out research on problems confronting agriculture that are:

> "national in range and scope, fundamental in character, and which require concentration, effort, and highly specialized research for their solution."

State Governments, on the other hand, were to have primary responsibility for the internal administration and regulation of agriculture, for providing advisory and extension services, for agricultural education and for a great deal of applied research. This research was described in the report as "of a more or less local character" which "involves the application of existing knowledge."

C.S.I.R.O.

The Act of Parliament which created CSIRO provides a deliberately wide charter and places upon the executive the responsibility for formulating the policies necessary to carry out these charges. The functions of CSIRO as defined by this Act are, briefly:

- Scientific research and application of the results;
- Overseas scientific liaison;
- Research training and funding;
- Research association support;
- Maintenance of measurement standards;
- Publication and dissemination of scientific information.

CSIRO is an independent, statutory body. ASTEC provides advice to the Government on encouraging science and technology to meet national needs, but it has no executive responsibility. CSIRO regards the role of ASTEC as complementary. ASTEC has observer status on the CSIRO Advisory Council.

The CSIRO holds responsibility for research in many other areas than agriculture, but not for the planning and execution of all national scientific research. Specifically excluded are clinical medicine, defense, nuclear research and the social sciences. In some other areas responsibility for planning research is shared with another organization.

The Independent Inquiry defined the purpose of the organization as "strategic, mission-oriented" work. "Mission-oriented," in this context, means research undertaken on an objective of national interest and "strategic" means work tending toward the basic or fundamental end of the research spectrum. The inquiry stressed the autonomy of the organization because, in its opinion,

> "The setting of priorities for, and the management of, strategic research are best handled by a scientifically oriented body consulting with users and their representatives."

CSIRO has this autonomy in setting research project objectives, subject to the discretion of the Minister of Science. It is specified that the Minister will intervene only as a "last resort" and that, when and if this happens, a complete explanation will be provided in the CSIRO Annual Report.

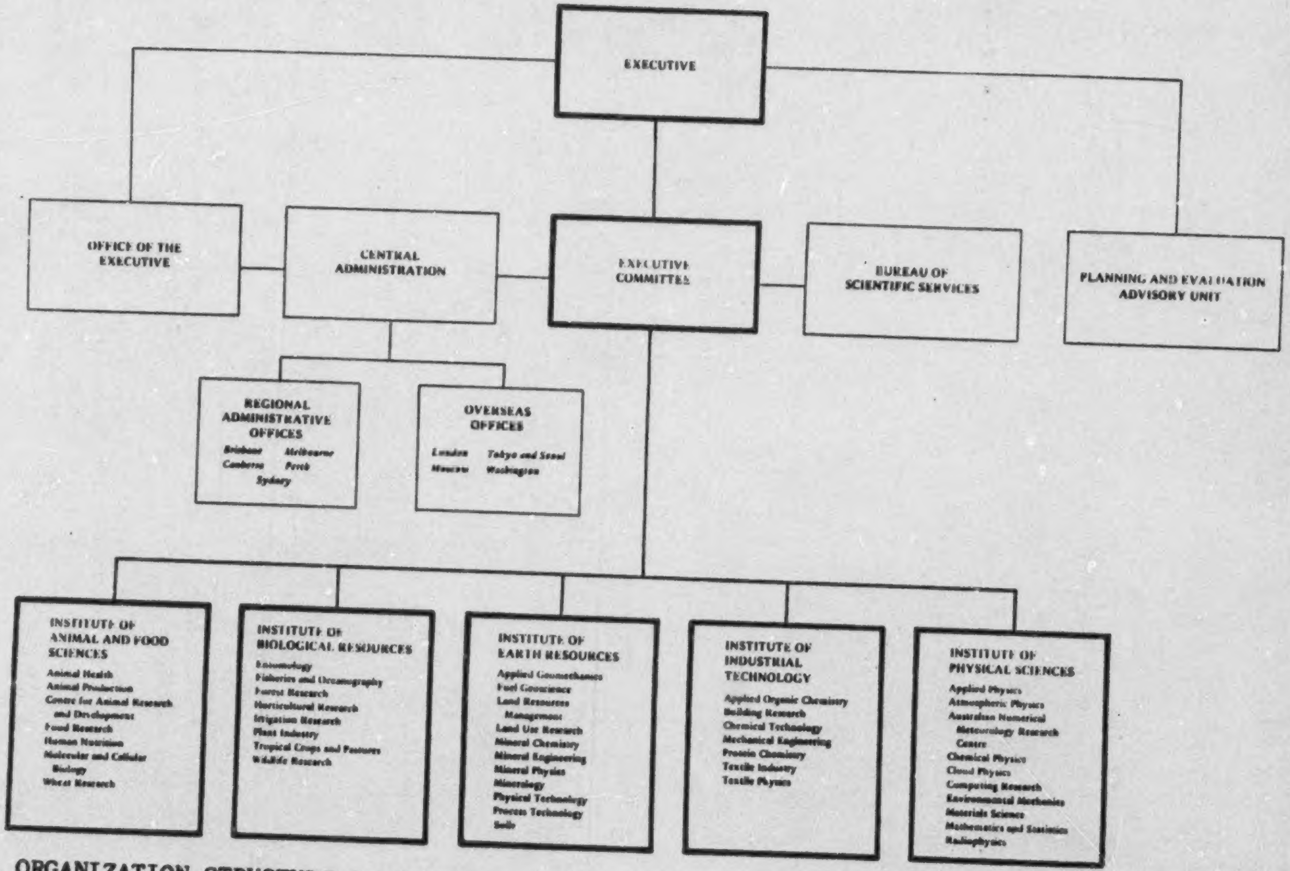
The CSIRO is not obliged to provide policy advice to the government but it does provide factual information to various government bodies upon request.

The CSIRO has the power to make inventions available, pay bonuses and charge fees for services. It also has the power to contract research work out to other bodies and to join in the formation of a partnership or company for the commercial development of an invention.

Organization and Administration.

In June of 1979, CSIRO had a total of 7,296 employees located in more than 100 laboratories and field stations throughout Australia. Approximately one-third of the staff are scientists.

Broad directions and areas of research are determined by the CSIRO executive in response to perceived natural needs and with advice from various sources. Following the independent inquiry into CSIRO in 1977 the various research units have been grouped into five Institutes and a Bureau of Scientific Services. Each Institute has a director in charge of several divisions and units. Individual research programs are largely the responsibility of the institute director in consultation with senior research staff.



ORGANIZATION STRUCTURE OF CSIRO. Source: C.S.I.R.O. Annual Report, 1978/79

The Executive is composed of three full-time and three to five part-time members. The latter must all come from outside the organization. The Executive is responsible for the development of policies for the entire organization and for internal management, relations with government and other institutions and for monitoring the effectiveness of the performance of the organization.

Advice is provided to the Executive by the Advisory Council in relation to both objectives and priorities and to relevant industrial and economical matters. This council is independent of CSIRO; Executive members are not eligible for appointment. Advice from the states is channeled through the chairman of each State Committee. This provides grass roots contact with industry, centers of education, and the community generally. In addition to these members there may be up to 15 additional members representing a wide range of interests. Ad hoc work groups may be set up by the Council to investigate particular areas of CSIRO activities.

Definition and Review of Programs.

The initiative for defining programs is seen primarily as a responsibility of the research staff. Broad outlets for a division are defined by the Executive.

The Executive executes a program of Divisional and Subject reviews. Committees of Inquiry are established with suitable outside representation and with wide-ranging terms of reference. Subject reviews may cross divisional boundaries, and are usually directed to identifying research needs and appropriate programs for a sector of industry.

Funding.

In 1978-1979, CSIRO's total expenditure was $A 167.9 million. For this budget, 89% of the income was provided directly by the Commonwealth Government and by revenue. Of the remaining 11%, about three-fifths was contributed from research funds concerned with various commodities. These funds are earmarked for research programs that have been established for a number of important agricultural industries (wool, wheat, eggs, honey, etc.). These programs are financed by a statutory levy on produce, with matching funds from the Commonwealth Government. Research committees for these programs are comprised of representatives from Commonwealth and State Governments, universities and primary producers.

Relations with Industry.

The Commonwealth Government has attempted to avoid research which, in the opinion of its advisors, could and should be carried out by industry. The CSIRO research effort is aimed at benefitting wide sections of industry; it is of a kind that could not economically be undertaken by individual companies. The government has, therefore, concentrated its effort on infrastructure support for industry such as physical standards, plant and animal biology, physical and chemical processes, and properties of materials.

Companies have been encouraged to design their own research programs to meet their needs. Excess research capacities of these firms may work on government research contracts, but these contracts are only let if it is clear that the industry laboratory can do the work more economically.

Where industrywide needs are obvious, research associations of industry members are formed. The CSIRO does make grants to these associations, as discussed in the "funding" section of this report. The research committees of these industry research associations play an important part in the overall management and coordination of the research. Not only do these committees allocate some $A 26m. in funds, but they determine the program to be undertaken and by whom. Progress of the research is monitored in detail and in-depth reviews may be conducted. These committees are often active in disseminating the results of research to their members.

As mentioned previously, the CSIRO may form agreements with industry to commercialize an invention.

The Independent Inquiry recommended that mechanisms be established in CSIRO to ensure that specialist advice and assistance in monitoring industrial trends and developments are available to the research staff and at the same time that industry should have access to CSIRO staff and informational sources in consulting capacities.

Consideration is being given to the imposition of producer levies on industries other than commodities, to support additional research.

The CSIRO is considering mechanisms for liaison with industry to promote the implementation of research results, particularly in the manufacturing industries.

A small proportion of the overall research and development activities in Australia is carried out by private industry. However, this percentage has increased in recent years due to a grants scheme initiated by the government to stimulate industrial research and development. These grants are made to approved research organizations and are designed to meet the needs of a particular industrial applicant. Many of the larger corporations have established their farmer research divisions as separate firms to which other firms in the corporation can then contract their research and be eligible for a government grant. In the year 1970/71 an estimated 84% of the grants were made to this sort of corporate arrangement.

Selective grants are made in accordance with a number of broad national interest criteria.

It is worthy of note that, while broad national interest criteria are employed in determining the eligibility of firms for selective grants under this scheme, applications for grants are not received and considered until after relevant expenditure has been incurred. There is therefore no selectivity, as between various industry groups or individual business enterprises, exercised in advance of the industrial research and development work being performed.

The Australian Government has also encouraged technological innovation by industry directly through financial incentives and indirectly through patent legislation, taxation and educational measures which provide a favorable economic climate for such innovation.

Relations with Higher Education.

The CSIRO is primarily an in-house research body and has not diverted much of its budget to educational institutions. The role of universities is seen to be the training of students, not the conduction of research for CSIRO. The CSIRO does award 15-20 postdoctoral fellowships and research fellowships to universities, provided that the work proposed is of particular interest to CSIRO and that the university is in agreement. These are viewed as grants rather than contracts.

The Independent Inquiry supported this basic philosophy of the relationships with institutes of higher education. It did suggest, however, that CSIRO

- Attempt to site new laboratory facilities adjacent to tertiary educational institutions.
- Investigate making research equipment available for university use, and aim for joint financing of such equipment.
- Promote sharing of staff with universities. (About 20% of the research staff is now involved in some teaching or student supervision.)
- Contract for an institute of higher learning to carry out research programs when the institute is clearly better able to carry out this work.

Staffing.

The CSIRO has sought to protect and encourage the natural creativity of its research personnel. The main characteristics of its staff policy are:

- Professional responsibility is encouraged by a great deal of autonomy and authority.
- Most staff with proven ability can have a career in research.
- There is no tenure. Appointments are for terms only. This encourages flexibility and the flow of new ideas.
- Advancement is largely based on merit, rather than availability of vacancies in a hierarchy.
- Merit is reviewed annually. The most important factor involved is peer assessment relative to publications, and the contribution to industry and the community through the implementation of research.

- Research staff are encouraged to follow a project to completion, even into extension aspects if so desired.

This staffing policy has led to a very high prestige for scientists associated with the CSIRO. This prestige is not only national, but world-wide.

Staff Development.

Since most of the research personnel have completed higher training programs, there is little in-house development. Programs have been devised to develop supervisory or managerial skills for those who now hold or are likely to hold supervisory positions. Courses cover research management (allocation of resources), management effectiveness, selection interviewing and counselling, use of microprocessors, technical photography, and purchasing techniques.

Extension Services

Agricultural extension services in Australia are mainly the responsibility of the State Department of Agriculture. However, the Commonwealth Government is important as a liaison between the states and in the administration of Commonwealth funds directed to extension services and research. The Commonwealth Extension Services Grant provides funds for the regional and applied research that is essential for an effective extension operation. Priorities for these funds are specified as staff training and support, informational services, and farm business management services.

The Commonwealth Council for Rural Research and Extension has the role of advising the Minister for Primary Industries regarding:

- A review of rural research and extension relative to the role of agriculture in the economy.
- Priority areas and new areas for research.
- The development of working relationships between various governmental agencies, the universities, and industry.
- Advice on measures to promote the application of research findings.

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BRAZIL

Agricultural Situation

Brazil is the largest and most populous country in Latin America. In territory it is the fifth largest country in the world but only 38% of the land is in agricultural production. Most of the remaining land is government land and most of that is considered to be non-arable.

Agriculture is extremely important to the economy of Brazil. The country is a major producer of food and fiber crops and these account for 62% of all exports. Agricultures contribution to the GNP has declined slightly, and estimates of importance vary. The World Bank calculated that in 1963 it accounted for 22.5% of the GNP and in 1973 for 17.4%. In 1979 one estimate placed this figure at 10-12% (1) and the Inter-American Development Bank in the same year suggested a figure of 7.5% (2).

Land holdings vary greatly in size and structure. There is a very large population of migrant workers (estimated at five million), many share-croppers, a great number of small farmers and a few holders of large acreages. It is estimated that 44% of the economically active population is engaged in agriculture. In the 1975 census, it was revealed that land holdings of 0-99 hectares accounted for 90% of the farms but for only a land area of 21.4% of that being farmed. The remaining 78.6% of the land was held by 10% of the farming population in holdings of more than 100 hectares. There is thus a great disparity between the many small farmers and the few big land holders.

There has been substantial migration from rural areas to the cities because of the great disparity in income of these sectors. This migration coupled with a high birth rate has accounted for large urban populations and fewer farmers to provide basic foodstuffs for both the domestic and export markets.

Agricultural Objectives

The major objectives of the present government are to raise rural incomes and production through more efficient use of the land resources, expanded credit for small producers and improved storage and marketing infrastructure. Brazil's comprehensive crop insurance program (PRO-AGRO) has been extended and minimum support prices have been increased greatly. These efforts are aimed at re-inforcing the priority of the agricultural sector as a major means of strengthening Brazil's balance of payments situation and of fighting inflation since rising food prices are particularly burdensome on low-income groups.

According to Heller (3), the lack of a coherent agricultural policy is what has prevented Brazil from becoming a major food exporting country. Agriculture is now the most important factor in the official economic policy of the new Administration. In 1979 a study was commissioned in "New Directions of Agricultural Policy" and this has resulted in a policy that:

- Recommends the exploration of new agricultural frontiers by large management consortia capable of introducing modern production techniques.

- Emphasizes the establishment in the traditional agricultural sector of national production and marketing schemes through cooperatives.

- Recommends an agrarian reform to improve efficiency and to bind the farmer to the land through access to ownership. This may be carried out through a simple revision of rural property taxation (1).

- Creates an efficient domestic commodities market to guarantee the producer a market for his crop.

- Aims to provide security to the farmers by negotiated minimum prices and the sale of stock with farmers associations before each crop is planted. This would involve consultation with producers and rural associations (4), a major change in policy. In the past the government's involvement with storage and the sale of surplus has been a source of instability in the agricultural sector (1).

- Encourages increased production through credit. This system has been instutionalized through the extension system.

Agricultural Research Policy

Until the mid-1940s, plantation agriculture was at its peak and the policy was to expand the agricultural frontier with major export crops such as coffee, cacao and sugar. In the mid-1950s, the industrial base was rapidly expanding and agriculture was largely ignored by the government. It has recently been acknowledged that expansion of the frontier alone cannot continue to meet the demands from both foreign and domestic markets and that higher productivity per unit area must be an objective of agricultural policy in the future. This kind of development will involve additional capital and technical inputs and more effective agricultural research is essential for the execution of this program.

COMPATER

National priorities for agricultural development and general policy and procedural matters are the responsibility of the National Committee for Agricultural Research, Technnical Assistance and Rival Extension (COMPATER). This group is charged with the coordination between research and extension efforts. It has the responsibility at the federal level for synchronizing, reviewing and coordinating the programs of research (EMBRAPA) and extension (EMBRATER). COMPATER is structured as follows:

Chaired by a representative of Minister of Agriculture

Members: President of EMBRAPA
President of EMBRATER
Representative of Central Bank
Representative of National Farmers Confederation
Representative of National Agricultural Confederation
Two representatives from outside of government

On this paper this appears to be a suitable medium for determining priorities, with representation of extension, research, planning, credit, and the farmers' organizations. However, a knowledgeable United States official told me that in fact, COMPATER has ceased to meet. The structure is such that the organization is funded jointly by EMBRAPA and EMBRATER and that these organizations, in charge of the budget, were in fact determining their own priorities.

Agricultural Research

The structure of agricultural research is currently in transition, from a very loosely administered group of about 230 research units operated by many different federal, state and private agencies to a more centralized arrangement where one federal authority is in charge of all agricultural research programs. The former approach suffered severely from the lack of any planning, coordination and guidance at the federal level, and, even at regional and state levels, the benefits of research were largely unused due to poor farmer support services. Complementary inputs, such as extension, credit and marketing, were often either entirely lacking or not available to a significant proportion of producers. Also, research efforts often failed to take into account the need for additional inputs such as credit. An examining committee surveyed the situation in 1972 and in response to a strong unified research corporation, Empresa Brasileira de Pesquisa Agropecuaria--EMBRAPA, was created by law in December 1972. This newly established corporation, linked to the Ministry of Agriculture, was charged with the full national responsibility for the coordination and promotion of agricultural research throughout Brazil.

The statutes of EMBRAPA are to: (a) direct, control and execute agricultural research activities for the purpose of producing new technology for the development of national agricultural production; (b) assist the Federal executive branch, and its entities, in technical and administrative matters related to the agricultural sector; (c) stimulate and promote the decentralization of research activities to the benefit of state and local interests; (d) provide technical coordination of research projects, the execution of which involves the technical-administrative services of other federal agencies, (e) maintain close contact and coordination with the Brazilian Technical Assistance and Rural Extension Corporation (EMBRATER) to effectively execute diffusion of research results and technology, and (f) plan, program and budget research activities to reflect the guidelines and policies established by the National Commission for Agricultural Research, Technical Assistance and Rural Extension (COMPATER).

EMBRAPA began operations in April, 1973. It took over the functions of the previous National Department of Agricultural Research (DNPEA) and was charged with responsibility for the coordination and promotion of agricultural research throughout Brazil. EMBRAPA will establish coordinated, multidisciplinary national research programs that involve EMBRAPA research centers, cooperating universities, and state and private agencies. It has the initial task of transforming the general production goals of the government into research programs geared to increase the productivity of land and labor. An important aim of the new structure is to organize and improve the skills of the scientific and technical staff who carry out the research programs (5).

The model of EMBRAPA is unique. Its initial management was strongly influenced by scientists trained as economists, rather than as researchers, and this orientation is still dominant. A primary concern was to dissociate from the DNPEA, of which the government examining committee had been so critical. That organization was a civil service branch and was top-heavy with poorly trained individuals who had little knowledge of national needs and virtually no communication with other researchers or with small producers.

The new model for organizing agricultural research is termed a public corporation. EMBRAPA is translated as the Brazilian Public Corporation for Agricultural Research. The agency operates like a public utility, being open to all types of financial arrangements. The principal product of the corporation is agricultural technology and the primary client is the government. It does have the autonomy to make financial arrangements other than direct research for the government, although the budget is allocated by the government and it is officially "linked" to the Ministry of Agriculture. Many authorities see the formation of the private company more as a way of separating from the government bureaucracy and from civil service salary and staffing policies than as a truly different organizational structure.

EMBRAPA is primarily concerned with applied research, seeking packages of technology that can be used by farmers immediately. More fundamental research is seen as the province of the universities. Research planning and management has focused on the adoption of a highly centralized system of management. Because the country is so large and agriculturally diverse there are many potential research areas that could improve productivity. However, shortages of trained personnel and, to a lesser extent, facilities and equipment have led to a concentration on a relatively few commodities.

The Chart of Management Structure illustrates the structure of EMBRAPA research programs.

a) Regional Agricultural Research Programs are concerned with the development of improved farming systems, including materials and practices, for the soils and climatic conditions in the three agro-ecological regions.

b) National Commodity Research Programs focus on the improvement of production for that particular commodity. Only one high priority commodity is covered per program and both domestic and foreign markets are of concern.

The research programs in (a) and (b) are organized around a major central station and a series of regional stations to cover the various agro-climatic regions in which various commodities are produced (6).

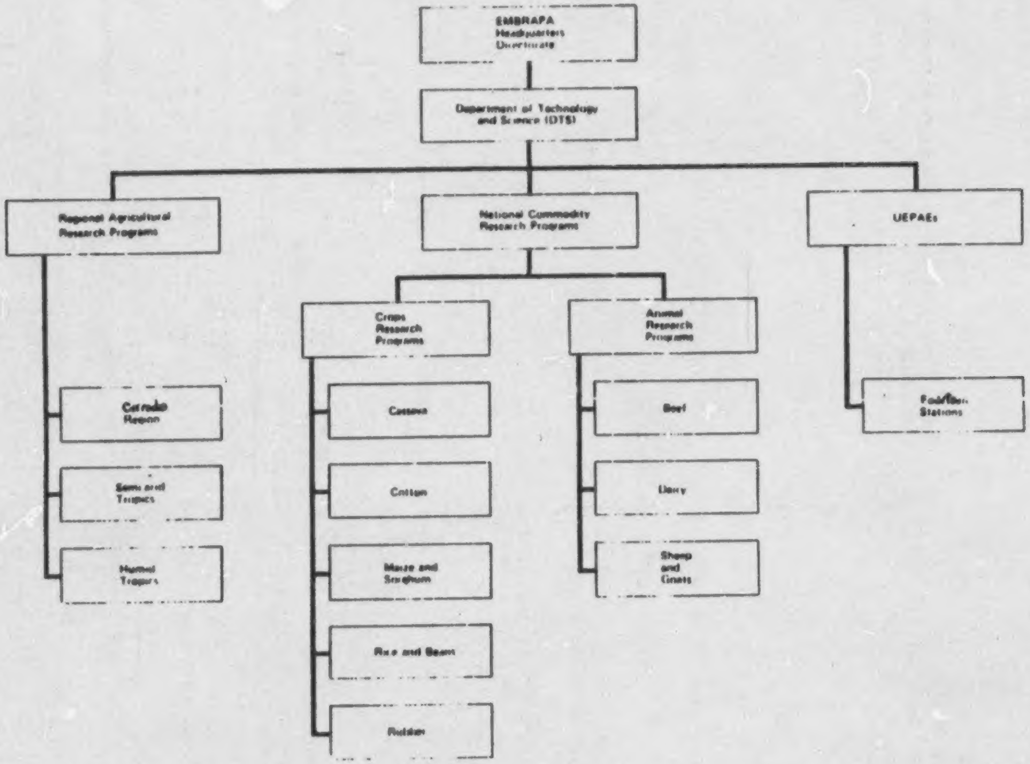
Under the original EMBRAPA plan, all state and agricultural research systems were to be brought under the control of the federal system. In some cases, however, the states have refused this arrangement and are considered "integrated" but not fully absorbed by EMBRAPA. In general, the State Research Systems carry out on-farm research, testing and adapting to local conditions. State companies run their own experiment stations and are attached to their own Departments of Agriculture (7).

c) VEPAE (State Agricultural Experiment Station). EMBRAPA has established 14 research stations at the state level to conduct adaptive research on improvement of farming systems for the regions in which they are located. This involves collaboration with (a) and (b) as appropriate. These state research agencies are the result of agreements between EMBRAPA and the State Department of Agriculture. In general these are located in states that did not have a research capability before the establishment of EMBRAPA.

d) In addition to these activities, EMBRAPA provides support for research on problems of high priority in agricultural development that are identified by EMBRAPA but jointly planned with a university of other institution that would conduct research under contract or cooperative agreement.

e) Also not included in the management chart are a number of "Special Services" provided by E,BRAPA. These include Centers of Genetic Resources, a National Center of Food Technology that coordinates all research in processing of agricultural goods, a National Service of Soil Surveying and Conservation,

PROPOSED MANAGEMENT STRUCTURE FOR EMBRAPA RESEARCH PROGRAMS



and a Service for the Production of Basic Seed to distribute seed developed by EMBRAPA.

ORGANIZATION AND ADMINISTRATION

Broad objectives are established in the National Development Plan. In theory, COMPATER serves as the Technical Advisory Council to EMBRAPA to ensure continuing awareness of national priorities.

The Directorate of EMBRAPA furnishes general policy and procedural guidance in the formulation of the total research program. The Board of Directors has a President and three Executive Directors. Priorities are set from within EMBRAPA and, according to United States experts, the staff analysts are all economists so that scientific researchers have little or no input to the setting of these priorities.

The national commodity and area research programs are to have the research program designed by the program leader, with the guidance of senior research scientists from the participating centers or institutions. Annual workshops for the identification of priorities are designed for scientist participation in the planning and direction of research.

Advisory councils are being established for national commodity and area programs, to identify priorities, help in planning, and to encourage the dissemination of technology. These councils would serve in an advisory, not management, capacity. A typical council would include:

a) one or more producers,

b) a representative of industry,

c) a representative of universities,

d) a representative of EMBRATER,

e) the national program leader/coordinator, and

f) a representative of EMBRAPA Department of Technology and Science and possibly other departments.

EMBRAPA is developing a Program Planning and Budgetary System (PPBS) to review research program planning, review, and budgeting. The national program leader/coordinator would have the primary responsibility for coordination of the research, for supervising researchers and for adhering to agreements made between collaborating institutions. The PPBS would facilitate the management, including effective coordination of multidisciplinary, multi-institutional research.

Funding

Although it has the legal status of a public company rather than a government department, EMBRAPA is almost totally dependent upon government budget allocations or government secured borrowing to finance its operations. EMBRAPA's annual or tri-annual budgets are subject to government approval as part of the budget of the Ministry of Agriculture. In 1974, roughly 72% of the funding came directly from the Federal Treasury, another 18% represented transfer of funds from other agencies linked with the Department of Agriculture, about 4% from a United States AID loan and the remainder from miscellaneous sources and sales of services and agricultural produce.

Since its inception, the budget of EMBRAPA has grown dramatically. This reflects the fact that the first years were focused mainly on planning and reorganizing the research system rather than an expansion. The 1975 budget was roughly U.S. $58 million, about triple the 1974 budget and accounting for about 12.5% of the total programmed expenditures of the Ministry of Agriculture. The budgets for subsequent years in U.S. dollars were 1976, $82 million, 1977, $98 million, 1978, $137 million and by 1980, $147 million.

Staffing

The reorganization of the Brazilian research system provided EMBRAPA with the opportunity to selectively employ research scientists from formerly independent research institutes and from the old government research system. These personnel could then be reassigned according to their abilities and preferences. The old system was overcrowded with bureaucratic personnel. The corporation was, by law, allowed to select those best suited for its work. It chose to employ 3,422 out of 6,705 employees in the old system.

Since EMBRAPA is not subject to civil service hiring restrictions, it is free to hire any scientist at a salary that is competitive with the national and international labor market.

Staff Development

There are not nearly enough adequately trained scientists to fulfill the research programs that are envisaged. EMBRAPA management has undertaken an extensive in-service training effort to upgrade the staff it has as well as a program of fellowships for training new graduates.

A current goal is to enable 1,000 researchers to obtain advanced degrees at Brazilian or foreign universities. Under the old system only 10% of researchers held graduate degrees; the aim of EMBRAPA is to have a scientific staff 80% of whom held graduate degrees.

EMBRAPA salaries now compare favorably with private industry. Through annual performance reviews, special individual achievements can be rewarded by salary increases and promotion, or both.

Relations with Industry

Until recently, interaction of government research and private industry has been slight. A major involvement has developed in the National Alcohol Program, aimed at developing alcohol for fuel. This is under the direction of the Ministry of Industry and Commerce which sets guidelines and goals and provides credit and financing for its implementation. This involves both the improvement and planting of crops, the production of alcohol, and research on its utilization in engines. The actual implementation on a commercial scale is left to private industry.

Rubber is another crop that falls under the jurisdiction of the Ministry of Industry and Commerce.

Sugar, coffee and cocoa are major export commodities from Brazil. Research and extension for these crops has been financed from funds derived from an export tax on the product. In the case of cocoa this tax was 15% on the beans and 5% on semi-processed materials (8).

Relations with Higher Education

Teaching, research and education are carried out by separate institutions in Brazil. In 1962 the Ministry of Agriculture was reorganized and rural universities became autonomous. Education is now the responsibility of the Minister of Education and there are no official links between EMBRAPA and the agricultural colleges.

EMBRAPA has recognized the need for trained personnel and has established a fellowship program under which the student signs a legal contract to work for EMBRAPA for a period at least equal to the fellowship study period. Latest available figures showed that 786 long-term (graduate degree) fellowships had been awarded and 180 short-term fellowships. Thirteen Brazilian universities have been classified by EMBRAPA as suitable for this training and about one-fifth of the Ph.D. training and four-fifths of the MSc. training will be carried out in these centers. The remainder of the students study abroad.

(Ruttan (6) has pointed out that recruitment by EMBRAPA of the most able researchers from the universities has jeopardized their ability to adequately train the next generation of agricultural scientists.)

EMBRAPA does not contract some basic research to institutions that are able to perform the work. The national research program may collaborate or interact directly with scientists at these institutions in specific areas of research that will help meet the objectives of the national program.

Extension (EMBRATER)

Technical assistance and rural extension activities in Brazil have long been fragmented, with responsibilities spread among several institutions which, in most cases, provide commodity services in only selected geographic areas. The most important of these institutions until mid-1974 was the Brazilian Association of Credit and Rural Technical Assistance (ABCAR), which was primarily responsible for disseminating agricultural technology to farmers. ABCAR operated through 23 state associations (ACARs), and all functioned as nonprofit civil corporations, technically and administratively independent.

This structure was financially weak and was linked only to those farmers who were receiving credit, the main objective being to assess the credit-worthiness of the client and to ensure that he undertook the technical improvements necessary to make his enterprise a success. This meant that the large landowners would seek extension help and credit and the small farmers were excluded. National research did not produce very much techniques that were relevant to the small farmer. There was no long-term planning of objectives.

The government has now created the Brazilian Enterprise for Technical Assistance and Rural Extension (EMBARTER) as an autonomous entity, a private corporation within the Ministry of Agriculture. Each of the state units of ABCAR are no reestablished as State Extension Companies (EMATERs) under EMBRATER guidelines.

The primary functions of EMBRATER are to collaborate with other agencies of the Ministry to formulate and implement policies pertaining to technical assistance and to promote, stimulate and coordinate technical assistance programs. Centralization of all federal budgetary allocations for extension services gives EMBRATER control over the state agencies which must comply with EMBRATER objectives to receive funding.

A wide range of institutions has been involved in the formulation of "Guidelines for the Operational Structure of EMBRATER." These guidelines were formulated by 15 working groups representing 49 public and private institutions plus 15 affiliates of the state systems.

EMBRATER has been organized to focus extension work on the national agricultural objectives. The major innovation of this system is the strengthening of the federal financial and technical support for the activities of the state affiliates and the re-orientation of the state system toward a broader range of farmers. The policy of the federal government is to encourage production through the use of credit and it is through this means that the extension service encourages farmers to adopt new technologies. Government influence is thus very great in the extension aspect, whereas the researchers of EMBRAPA may formulate their own priorities to a large extent.

Linkage between EMBRAPA and EMBRATER is very close. The Department of Diffusion of Technology (DDT) within EMBRAPA and the Department of Technical Support (DTS) of EMBRATER act as liaison units. At the state level, the representative departments responsible for diffusion of technology in the two institutions will work together. The main point of contact between research and extension is intended to be at the farm level and extension bulletins are to be prepared as a result of discussions between researchers, farmers and extension staff.

Evaluation of Success of Reorganization

Because the reorganization of the national agricultural research system took place as recently as April 1973 it is too early to judge its effectiveness, particularly in a country of the size and agricultural diversity of Brazil. By the establishment of EMBRAPA and EMBRATER the government has acknowledged the importance of agriculture to the overall economy and has made the first moves toward a more integrated system. Initial figures are not encouraging, however. In the decade of the 1970s production of foodstuffs per capita actually declined and the prices of agricultural products increased twofold relative to industrial prices.

A major aim of the new system was to increase the inputs of various interested parties into the determination of priorities and policies. As mentioned earlier in this paper, COMPATER was charged with the coordination of programs and this group has not met for several years. In some instances, the inputs have increased. For example, in the Comado region a major agricultural cooperative has set up a research station in which both federal and state agents are working. This is the exception rather than the rule and broad input of producers concerns are still marginal for the country as a whole.

The equitable extension of credit to all producers was another aim of the new arrangement. These loans are administered by EMBRATER as a means of coercing farmers into working with the extension service. However, in March 1979, one of Brazil's leading authorities on rural affairs reported (3) that only 20% of the farmers had access to credit and to minimum farm prices. Available statistics reveal that in 1976, for instance, small, medium, and large producers obtained 11.3%, 35.09%, and 53.53% of the total value of rural credit contracts, respectively. In 1966, these same figures were 34.12%, 45.60%, and 20.27%, respectively. The situation for the small producers has, therefore, considerably worsened although this cannot be attributed entirely to the new arrangement.

The entire agricultural sector of Brazil suffers from a lack of governmental infrastructure projects. There is no national transport scheme. Seventy percent of the transport of agricultural products is by truck on very poor roads. Transport by waterways has not been developed. Storage facilities are totally inadequate. For crops of 45 million tons storage is only available for 28 tons. More processing in lieu of storage might encourage more foreign investment.

All of these concerns (agrarian reform, rural taxation policies, governmental infrastructure, and greater participation by producers) can be expected to take time. High rates of inflation, illiteracy and birth complicate any advance. Progress of the new system has not been dramatic, but it appears too early to declare the structure a failure.

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INDIA

Agricultural Situation

For nearly three decades an independent India has been struggling under a partially planned economy to make significant gains in the modernization of her agriculture. Agricultural development has become an increasingly important element in a series of Government Five-Year Plans (1).

India is a predominantly agrarian economy where more than 80% of the population lives in villages. Its present government believes the solution to India's massive problems of poverty and unemployment lies in the development of agriculture and integrated development of rural areas. During the current Five Year Plan (Sixth Plan 1978-83), the government has made a policy decision to give maximum emphasis to agriculture and rural development.

A few years ago, many experts were predicting that India could never become self-sufficient in its food requirements (15). Current trends in Indian agriculture are most promising. The growth rate in grain production from 1949 through 1977, excluding two years of extreme drought in the mid-1960s, has been at an average rate of 2.57% annually. The growth rate for agricultural production overall has been 2.60% versus a population growth rate estimated to have decelerated to 1.9% annually. Further, the growth rate for agriculture is projected to have the potential to remain at 2.5% to 2.6% per year over the next two decades through the use of modern agricultural technology (i.e., irrigation, high-yield seed, multiple cropping, etc.) (3). Agricultural research and development has become an important element in India's startegy for economic development.

Agricultural Objectives

The priority given to agricultural development by the Indian Government under a series of Five-Year Plans has varied. Under her First Plan, agriculture was given the highest priority. During the period of the Second and Third Five-Year Plans (1956-61 and 1961-66) agriculture was neglected in the late 1950s and then again somewhat rehabilitated at the end of that decade. Subsequent Five-Year Plans have increasingly stressed the importance of agricultural development for India over other national priorities (22).

The recent change in priorities grew out of the Indian government's concern for stagnating food production in the late 1950s. This led to a desire on the part of the government to launch a "new strategy" for agricultural development. A key factor in this shift of government priorities, away from accent on industrialization versus agricultural in the Second Plan, was lack of increased productivity in the agricultural sector.

Increases in both production of food grains and in their yields per hectare had been quite steady until the mid-1950s but were stagnating by 1957-58 (22).

Since this period, agriculture has again become a first priority with the government. The current Sixth Five-Year Plan has very broad objectives for both agricultural and rural development. The current plan stresses extensive technical assistance to the rural farm sector of appropriate intensive agricultural practices (21). In line with this policy, the government has raised the share of agriculture and rural development to over 40% of available public sector investible resources (21).

Agricultural Research Policy

Due to India's current economic conditions and its population pressure, the identification of general research priorities is relatively simple. The central theme is that the number one priority is the attainment of food self-sufficiency.

Second is the achievement of stability of food production on a year-to-year basis in order to avoid periodic famines (5).

Third, government agricultural research programs have as their goals improving the economic lot of their farming communities, in particular the income potential of small farms. India is a country where the majority of land holdings are rather small (75% of land holdings are below two hectares) (5).

Faced with the above priorities, Indian Government research policy developers have stressed technical development programs which are problem-oriented and problem-solving. Their national research system places maximum emphasis on applied research (3).

Areas of agricultural development which receive a great deal of attention from research administrators are intensive agricultural development programs, model agronomic centers for testing new crop feasibility and National demonstration programs for new equipment and farming methods.

Agricultural Research

At the time of Independence in 1947, Indian leaders were aware that the existing agricultural institutions and research programs were ineffective in advancing the country's primitive agriculture (22).

The Indian agricultural research system was developed by the colonial government to meet the special needs of commercial crops such as sugarcane, coffee, cotton, tea, jute and rice. Organizationally, there were various central research institutes under the Ministry of Food and Agriculture and a number of central commodity committees acting independently in the area of research. Agricultural research on a national basis was marked by little central coordination of activities (13). Administration of the agricultural research system was complicated during both the colonial and early post-colonial periods by the division of responsibilities by a state-federal system of government in which agriculture has been designated as a state responsibility, with primary fiscal resources under the control of the central government.

In 1919 a constitutional change had made agriculture a provincial responsibility in India. In an attempt to coordinate research on a countrywide basis a central agency was formed in 1929. This agency--the Imperial Council on Agricultural Research--never achieved a prominent role in coordinating and promoting research. Leadership of agricultural research during the late colonial period was under a series of Central Commodity Committees which were established to promote the research, development and marketing of commercial crops with substantial export potential. These committees were concerned primarily with non-food crops with the exception of rice and wheat.

India was one of Britain's most important colonies for production of raw materials (i.e., cotton) and a major market for her finished goods. This was reflected in colonial Britain's approach to the problems connected with agricultural research and development.

After India attained independence in 1947, a new awareness of the problems connected with her economic development was felt in the country (3). Agriculture is by far the most important industry in the country and government planners have had to keep the attainment of self-sufficiency in agricultural production as one of their main objectives. During the last three decades it has been well recognized and appreciated that agricultural research is the foundation for increased agricultural production in India (3).

The "Green Revolution" in India is the result of the systematic application of improved agricultural technology for crop production. Government policymakers have recognized that improved agricultural technology stems from problem-oriented research; therefore, maximum attention has been given to organizations conducting research.

Following Independence, a number of expert teams were organized to review the Indian agricultural research systems and make recommendations to the government for their improvement. The following teams examined the agricultural system in great detail and made important recommendations.

- The First Joint Indo-American Team on Agricultural Research and Education (1955).
- The Second Joint Indo-American Team on Agricultural Education, Research and Extension (1959).
- The Agricultural Administration Committee (Nalagarh Committee).
- The Committee for Agricultural Universities Legislation (Cummings Committee) (1962).
- The Agricultural Research Review Team (1963).

The recommendations of many of these studies tended to overlap, primarily due to the slowness in implementation of recommendations made at earlier stages. Each successive team would take into account the recommendations of previous teams as well as the progress made in the implementation of their recommendations (3).

The First Indo-American Team concluded that the research institutes were, in general, ineffective in producing scientific or administrative leadership for the large number of central and state research efforts. The institutes were organized as subordinate offices of the Ministry of Food and Agriculture and were individually responsible to different sections or administrative heads in the Ministry. Not even the research supported directly by the Ministry was subjected to adequate internal coordination (26).

One major result of the report of the two joint Indo-American teams was to reinforce the efforts to establish a major research-oriented agricultural university in each state. The first agricultural university came into existence at Pantnagar, Utta Pradesh in 1960 (26).

Little else of significance was accomplished as a result of the several review teams reports until after the report of the Agricultural Research Review Team of 1963. This team, composed of eminent scientists from India, the United Kingdom and the United States, was appointed during a period of increasing concern about India's capacity to meet its food requirements. The team was appointed on October 31, 1963 and submitted its report on March 19, 1964. Within a year's time, the Government of India had decided to substantially reorganize its agricultural research system (26).

Other factors that have played a significant role in the development of the agricultural research system have been the excellent cooperation between the Indian organizations and outside participating agencies such as the Ford Foundation, the Rockefeller Foundation, AID, and American land-grant universities (i.e., University of Illinois, Ohio State University) (19).

Organization and Administration

A key factor in India's current agricultural development is the Indian Council of Agricultural Research (ICAR). The ICAR is the central agency for coordinating, directing and promoting agricultural research and education in the entire country. One of the key recommendations arising from the effort of the Agricultural Review Team in 1963 was the defining of a central role for ICAR in agricultural research.

The current organization had its beginning in 1929 as the Imperial Council of Agricultural Research. The Council had broad aims and objectives as evident from its charter:

- To undertake, aid, promote and coordinate agricultural and animal husbandry education, research and its application in practice, development and marketing by all means calculated to increase scientific knowledge of the subjects and to secure its adoption in every-day practice.
- To act as a clearinghouse of information not only in regard to research but also in regard to agricultural and veterinary matters generally.
- To establish and maintain a research and reference library in pursuance of the objects of the Society with reading and writing rooms and to funish the same with books, reviews, magazines, newspapers and other publications.
- To do all other such things as the Society may consider necessary, incidental or conducive to the attainment of the above objects.

Although this organization was entrusted with wide responsibilities, the Council never played a prominent role in coordinating and promoting agricultural research during the colonial and early post-colonial period.

The Council, prior to the mid-1960s, had no control over the Research Institutes which were administered by the Indian Ministry of Food and Agriculture. ICAR did not directly operate research institutes of its own. The Council gave ad hoc grants to various research institutes (including the Central Research Institutes), universities and other research organizations. A substantial part of the support for research on a number of major crops of commercial importance was provided by the Central Commodity Committees (i.e., cotton, sugar cane, tobacco, etc.).

In 1966, the Council underwent a significant reorganization as recommended by the Agricultural Research Review Team, which strengthened the infrastructure for agricultural research in India. The government implemented a reorganization of the Council on the following lines:

1) The reconstitution of the Indian Council of Agricultural Research as a fully autonomous organization, without changing its previous name.

2) The bringing of all research institutions under the control of the Departments of Food and Agriculture, including those under the Central Commodity Committees, under the reorganized Council.

3) The reconstitution of the governing body of the Council with a view to making it predominantly a body of scientists and others with an interest in or knowlege of agriculture.

4) The recognition of the Indian Agricultural Research Institute (New Delhi), the Indian Veterinary Research Institute (Izatnagar), and the National Dairy Research Institute (Karnal) as Institutes of national importance, and the delegation to these and other institutes of enhanced administrative and financial powers.

5) The granting of financial assistance for research to state institutes and universities by the reorganized Council in the form of block grants, on the model of the Atomic Energy Commission.

6) The making of arrangements for recruitment to scientific posts through the Council's own selection committee consisting of outstanding scientists.

7) The appointment of an agricultural scientist as the chief executive of the Council, with the designation of Director-General.

The restructuring of the ICAR in 1965-66 was a landmark. The Governing Body of the Council was reconstituted with a career scientist appointed as the Director-General and Vice-President of the Council. Dr. B. P. Pal, an eminent agricultural scientist was appointed the first Director-General. To assist the Director-General on the technical side, four posts of Deputy Director-General were created and filled by eminent scientists. These positions included one Deputy Director each for (a) Crop Sciences, (b) Soils, Agronomy, Irrigation, Agricultural Engineering, (c) Animal Sciences and (d) Education (23).

The rules and bylaws of the Council were also revised at that time to make it more truly a functional, technically competent and adequately autonomous organization (23).

One of the first steps taken under the reorganization transferred all the central research institutes, which had been under the direct administrative control of the Department of Agriculture or the Department of Food, to the ICAR. These central research institutes became constituents units of the Council. By Council policy these institutes or "constituent units" function as the executing arm of the Council and all research programs undertaken by the Council are conducted through the institutes. Writers (3)(23) reporting on the Indian research organization stress the use of the term "constituent units" in referring to these research institutes since it is the policy of the Council that institutions doing scientific research should not be organizationally subordinated to ICAR.

It was decided to abolish all Commodity Committees and to place their research directly under ICAR. At the time of the reorganization the abolition of the Commodity Committees and the transfer of their research work to the Council was accomplished in less than a year.

With the reorganization, ICAR became the source for central government funding for the research activities of the Indian agricultural universities.

Though the responsibility of the ICAR and the scope of its activities were greatly enlarged after the reorganization in 1965-66, it continued to remain as an attached office of the Department of Agriculture of the Government of India, thus limiting its effectiveness. Again, although the personnel policies in the recruitment system had been modified by the ICAR after the reorganization, it was felt that some further changes were required (23).

A high-level Committee appointed by the Government of India in 1972 recommended the restructuring of the ICAR so as to confer on it greater autonomy and flexibility in its operational and management procedures. It recommended the establishment of a Department of Agricultural Research and Education in the Ministry of Agriculture to provide the requisite linkages with the Central and State agencies and in international collaboration in Agricultural Research and Education (23).

The Director-General, ICAR was designated concurrently as Secretary to the Government of India in this new Department of Agricultural Research and Education. The Committee recommended the setting up of a special Agricultural Scientists Recruitment Board with an eminent agricultural scientist as whole-time chairman, and also the setting up of executive and management committees in the research institutes to broadbase the decisionmaking process and to ensure effective implementation of approved research and training programs. The ICAR has thus undergone a further process of restructuring and strengthening in the recent period (23).

At present, the Union Minister for Agriculture and Irrigation is the President of the Council, and the Minister of State in the Ministry dealing with ICAR affairs is the Vice-President. The Council functions through a Governing Body which is presided over by the Director-General of the Council who is also Secretary to the Department of Agricultural Research and Education of the Government of India (23).

Besides the Governing Body there is a Standing Finance Committee, the Norms and Accreditation Committee, Regional Committees are Scientific Panels under the Council and 33 research institutes and four project directorates. The Council deals with 21 agricultural universities in addition to the Indian Agricultural Research Institutes which has the status of a postgraduate university (23).

Basic or fundamental research is conducted mainly at selective research centers. Many of the ICAR institutes depend upon the Indian Agricultural Research Institute and other national institutes for basic and background research (3).

Indian authorities on research organization often stress the importance of coordinated multi-disciplinary projects and the need to shape government agricultural research and development efforts to the national objectives while recognizing the unique problem in local areas (i.e., dry land farming). The present and future strength of agricultural research in India is dependent on a "partnership in" between the central and state agencies (3).

The Council is running a large number of All-India Coordinated Research Projects on food crops, commercial crops, horticultural crops; on soil, agronomy and agricultural engineering; breeding and improvement of the important farm animals and also in the field of fisheries. There are now a large number of operational research projects (23).

All-India Coordinated Research Projects

A number of authorities believe that the most innovative event contributing towards Indian agricultural growth was the initiation of the All-India Coordinated Research Projects (4).

All-India Coordinated Research Projects (AICRP) are programs to carry out research on various crops and farming systems in different agro-climatic zones, irrespective of state boundaries. The All-India Coordinated Research Projects are formulated by the ICAR to provide for effective planning and executing of agricultural research on a national basis. These plans recognize that in order to achieve full benefits from the limited facilities available and to make maximum use of the best talents of the country, irrespective of whether the resources are in a Central Government laboratory or in state research organizations, the full coordination of use of all available resources is essential.

The financing of ad hoc research schemes in an isolated and uncoordinated manner, as was generally done in the past by the ICAR and the Commodity Committees, was considered not effective for the solution of problems of the country as a whole by Indian policymakers. The present strength of agricultural research in India rests in the new sense of partnership between the central and state agencies for attainment of common national agricultural goals (3).

The more comprehensive All-India projects for agriculture are based on the following principles:

1) Research is problem-oriented.

2) Research efforts are intensified at selected centers for tackling important problems to support the new strategy of agriculture.

3) Research is strengthened in a center where leadership and the desired facilities are available.

In formulating the All-India coordinated research projects, the problem is visualized for the country as a whole. Research centers and sub-centers are located in different parts of the country to meet the needs of distinct agro-climatic zones and regions rather than for individual states (3).

Efforts are made to consolidate and intensify research at a few selected centers representing different soil and climatic conditions to insure efficient use of limited research resources. The central research institutes and the state agencies (agricultural universities or state departments of agriculture) work as partners so that all efforts are complementary rather than competitive (3).

Another important feature of the coordinated projects is their multidisciplinary approach. For example, in a coordinated project for crop improvement where the main emphasis is on breeding of superior varieties, research is simultaneously carried out in agronomy, plant pathology, entomology and biochemistry, etc., so that all facets of a problem are tackled. Good teamwork among the scientists from different disciplines and at different centers is vital to the success of the All-India coordinated research programs. The project coordinator is an active and capable research scientist. The technical planning is done on an All-India basis at the annual or periodic workshop or meeting of the participating scientists (3).

The first All-India Coordinated Research Project was formulated and implemented in 1957. This project--All-India Coordinated Maize Improvement Project--proceeded with the collaboration of the Rockefeller Foundation. In this project, instead of financing research on the old pattern based on the political boundaries of the States, the new approach considered the subcontinent as a whole, and divided it into major agro-climatic zones. In each zone, a major research station working on maize was located, while some substations were provided to look after the special needs of sub-regions (23).

In formulating a program for maize improvement for the whole country, the Council invited all the maize scientists of India to a meeting to discuss the problems of maize improvement and to develop a program. For the first time, scientists working in Central or States Institutes became involved in a countrywide cooperative endeavor.

A world collection of genetic material for plant breeders was provided by the Rockefeller Foundation. This project gave excellent results, and outstanding double crosses in maize became available in a short period of time (22).

A particularly successful similar program has been the All-India Coordinated Wheat Improvement Project (3). Another successful program is the All-India Coordinated Rice Improvement Project (6). In fact, claims are made by government officials that "India now has to its credit such achievements as a self-sufficiency in grain supply" due to such programs (1).

Agricultural Universities

After independence in 1947, India asked the United States to help her establish institutions similar to the American land-grant colleges and universities. This started a partnership that lasted for 20 years. Through the mechanism of Indo-American agreements and United States-financed technical assistance contracts, six United States land-grant universities (University of Illinois, Kansas State University, University of Missouri, Ohio State University, Pennsylvania State University and University of Tennessee) by 1972 helped India established nine new agricultural universities (27).

This massive pioneering effort to redirect India's system of higher agricultural education started in 1952 with the signing of the first AID-university contract and was phased out in 1972-73 at the request of the government of India (22).

During those 20 years, more than 300 staff members from the six United States universities accepted assignments in India and more than a thousand Indian faculty members and graduate students studied in the United States.

A key factor in the formation of the Indo-American partnership to upgrade the Indian agricultural educational system was the recommendation of the University Education Commission in 1947, which was formed by the Government of India to help establish guidelines for the nature, scope and role of university education in India. This commission recommended that special attention be paid to higher education in rural areas (17).

The establishment of these agricultural Universities was considered to be a major turning point in agricultural education in India. The first Agricultural University was established at Pontuagar in Utta-Pradesh in 1960. The University of Illinois furnished the technical guidance under AID financing. Others soon followed. The Agricultural University of the Punjab developed under this program was particularly effective and was a pace-setter among the group of emerging Indian agriculture institutions. Ohio State University furnished technical assistance with AID financing (24).

The pattern followed in developing these new agricultural universities was as follows (24).

1) It recognizes a responsibility and responsiveness to the needs of cultivators in contrast with being only a seat of learning and scholarship, and assumes a responsibility for working towards the economic development and improvement of the standard of living of the people of the state.

2) In addition to resident teaching for degree candidates, the staff also have responsibility for applied as well as fundamental research in agriculture. Such research must go beyond the laboratory and into the fields and homes, and with the livestock, under varying conditions found in different parts of the State.

3) The chief medium through which the cultivators are to derive the benefits of the training programs and of the research work under the agricultural university, is the extension limb of the university, which should be fully integrated with teaching and research organizations so that a smooth and effective flow of the results of research and of the training programs to the cultivators will be possible and the problems of the cultivators may similarly be transmitted back to the teaching and training centers for being tackled promptly and effectively.

4) The territory of the university with respect to the agricultural and related sciences should include the entire state, in keeping with the above principles and responsibilities.

5) The curricula and the training programs should be modelled in a manner as to be in keeping with the needs of the state on the one hand and of the aptitudes and needs of the individual students or trainees on the other. This must involve the formulation of a flexible curriculum with suitable provisions for courses of instruction in a wide field and the appointment of teachers who have specialized in their respective disciplines.

The Indian Government recently conducted a thorough review of their agricultural universities by an expert committee. This group, the Review Committee on Agricultural Universities, reported in 1978 that the universities had made a tremendous impact on agricultural production. The Review Committee also made suggestions for the future as follows: In the areas of practical training (field experience and programs to develop self-employment in agriculture), research programs (setting up of centers of excellence at selected universities) and educational programs (more broadbased general programs rather than early specialization) (20). In addition, the Committee recommended the need to decentralize extension activities by involving the regional research stations and the campuses in the extension education program. The role of the State governments was stressed. The Committee recommended that financial assistance to agricultural universities should be raised to the level of at least 10% to 20% of the agricultural budget of the State. Specifically, the Committee stressed the important role of State Governments in agriculture as follows: (20)

> The State Government should adopt a positive policy of support to agricultural universities.
>
> Firstly, they should review the University Acts and bring them in line with the Model Act recommended by the ICAR and implement it faithfully. They should transfer statewide agricultural research responsibility to agricultural universities along with staff, farms, budget, building, equipment, one Parallel research organization should not be set up in the State Department in the name of adaptive research.
>
> Secondly, agricultural universities are essentially state institutions and as such State Government should accept direct responsibility for both the development and operational costs. The central support from the ICAR could only be supplementary in nature.

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JAPAN

Agricultural Situation

Arable land in Japan comprises only 15.4% of the total land area. The limited land resources and the high population density mean that farms are very small. Average farm size is about one hectare. Only 6% of the farms have more than two hectares (4).

Most farms are family-owned. Agricultural growth since the Meiji Restoration (1868) has been achieved without disrupting Japan's traditional rural structure. This growth has resulted from large increases in yield per unit of land. Agricultural production increased steadily through the 1960s, but has declined since. In the fiscal year 1960-61, agriculture accounted for 10.2% of the GNP, but in 1972-73 for only 4.2%. A parallel change has taken place in the structure of farm households. There has been a movement of rural labor to industrial work, with the percent of the population involved in farming as the primary source of income declining from 26.8% in 1960-61 to 13.3% in 1972-73.

Agricultural Objectives

The agricultural policies of the government have been:

- To support farmers' incomes in a period of modernization and reduced manpower needs in the agriculture sector.
- To preserve a viable rural sector and slow the exodus to already crowded urban centers.
- To promote the rationalization and modernization of Japanese agriculture.
- To preserve a high level of food sufficiency and the capacity to revert to self-sufficiency as insurance against interruptions of imports of food products.

As Sanderson discussed (6), Japan has been successful in the first of these two objectives. Farm income has risen to parity with that of industrial workers, but largely because of the part-time nature of farming. In 1974, 72% of the total income of farm households was derived from off-farm labor. Farmers have not moved to the cities; however, this has also prevented the amalgamation of farms into larger units that are more economically viable. Small farmers have, however, formed very successful and powerful cooperatives to pursue these economies of scale. So influential are these cooperatives that a United States agricultural attache was quoted (3) as saying that "agricultural policy in Japan is really made by the cooperatives."

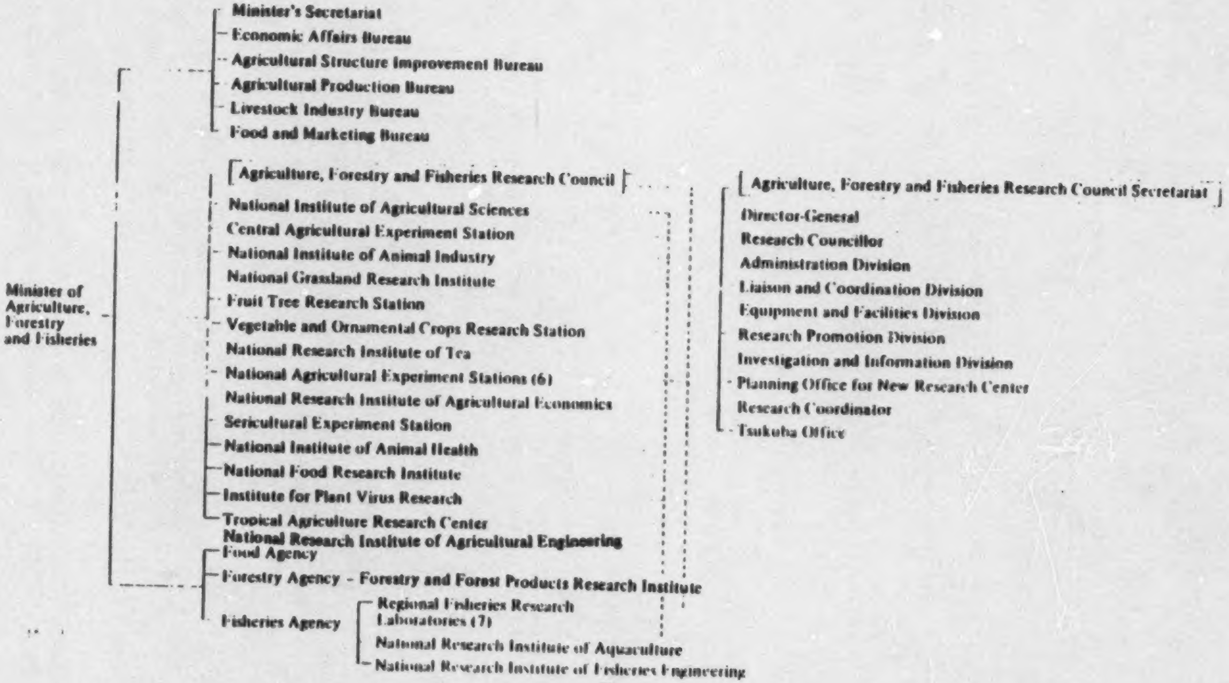
The small size of farms in Japan and the high population density provide an advantage for high-value foods such as fruits, vegetables, poultry and dairy products. This trend has been supported by the government but is impeded by the effort involved to support the production of cereal grains in the name of "self-sufficiency." This has resulted in what Lewis called "Japan's vicious circle of rice" (2). The search for food security has led to a vast over-supply of rice at a time when domestic consumption is declining. The government buys the rice for considerably more than it sells it to distributors. In 1975 the government spent 1.63 trillion yen to buy rice.

The self-sufficiency aim was reinforced in 1973 after an embargo of soybean sales to Japan by the United States. Guaranteed sales of rice provided a reliable income to small farmers; they now work in industry and the women produce a harvest which is extremely valuable. There is little incentive for farmers to change from this profitable life style.

Since 1975, the Ministry of Agriculture, Forestry and Fisheries has been trying to implement a program of "integrated food policies." The aim of this is to enlarge domestic production, with a target of 75% self-sufficiency by 1985. Donnelly (3) summarized the goals:

- The development of some new arable land and the restroation of double-cropping to increase the overall planted area by 836,000 hectares.
- The promotion of wheat, barley, soybean and rapeseed production.
- The promotion of forage production through acreage payments.

ORGANIZATIONAL STRUCTURE OF THE MINISTRY OF AGRICULTURE, FORESTRY AND FISHERIES


Minister of Agriculture, Forestry and Fisheries
Minister's Secretariat
Economic Affairs Bureau
Agricultural Structure Improvement Bureau
Agricultural Production Bureau
Livestock Industry Bureau
Food and Marketing Bureau
Agriculture, Forestry and Fisheries Research Council
National Institute of Agricultural Sciences
Central Agricultural Experiment Station
National Institute of Animal Industry
National Grassland Research Institute
Fruit Tree Research Station
Vegetable and Ornamental Crops Research Station
National Research Institute of Tea
National Agricultural Experiment Stations (6)
National Research Institute of Agricultural Economics
Sericultural Experiment Station
National Institute of Animal Health
National Food Research Institute
Institute for Plant Virus Research
Tropical Agriculture Research Center
National Research Institute of Agricultural Engineering
Food Agency
Forestry Agency - Forestry and Forest Products Research Institute
Fisheries Agency
Regional Fisheries Research Laboratories (7)
National Research Institute of Aquaculture
National Research Institute of Fisheries Engineering
Agriculture, Forestry and Fisheries Research Council Secretariat
Director-General
Research Councillor
Administration Division
Liaison and Coordination Division
Equipment and Facilities Division
Research Promotion Division
Investigation and Information Division
Planning Office for New Research Center
Research Coordinator
Tsukuba Office

Source: Embassy of Japau, Washington, D.C.

- Renewed efforts to encourage full-time farming.

- The use of price policies to encourage the production of food rather than as welfare policies to guarantee farm incomes.

- The continuation of the rice-diversion program to encourage the production of other food crops.

- Assistance to the fishing industry to develop marine resources in waters near Japan.

- The development of new food resources.

- The promption of rice consumption.

Most economists find these objectives to be too expensive and difficult to achieve. One study places the net social cost at the equivalent of 25% of the 1976-77 GNP (7).

Agricultural Research Policy

Because of the political influence of farmers' organizations, agricultural research has been distorted from what most observers see as the national interest. Ruttan (8) discussed the example of the inconsistency between agricultural policy and the resources provided for rice research. At a time when there is a surplus of rice that is costing the government huge sums of money, there are three national centers for rice breeding which, together with three other national research stations and eight prefectural (state) stations, are engaged in research to improve yields of rice and to lower costs of production.

Agricultural Research

The central government has played the major role in the organization and funding of agricultural research since the Meiji Restoration in 1868. Since farms were small and communication between farmers was poor, there was little chance of the involvement of private enterprise at that point. The government perceived Japan as an agricultural country and undertook the establishment of a research system.

Attempts to introduce farm machinery and expertise from the West in the early stages were unsuccessful. The size of the holdings and traditions of farmers were not compatible with these approaches. The next effort was the establishment of agricultural efforts along German lines of soil chemistry and the rationalization and extension of indigenous technology, using experienced farmers as instructors to spread varieties of seeds and techniques that they had developed.

In 1893 national agricultural experiment stations were set up to test varieties of rice in a number of locations. As early as 1899, prefectural stations were established to expand agriculture at the prefectural level. During the 1920s, an extremely effective program of national coordinated crop breeding took shape in which research planning, selection of parents and initial crosses to the F2 generation were carried out in the national center and these lines were provided to prefectural stations to test and adapt to local conditions.

Since the Second World War, prefectural stations have had more and more autonomy. Between 65% and 75% of expenditures for research in Japan are allocated at the prefectural level. National experiment stations are involved in basic, fundamental research and now play no role in the coordination of research efforts.

Hayami and Akino (10) examined both research expenditures and personnel and discovered that 59% of agricultural research is conducted at government institutions, nearly 38% at universities and just over 3% in the private sector. This contrasts with non-agricultural research, where approximately 80% is conducted in the private sector and only four percent by the national government, 2% by prefectural governments and 14% by universities.

Organization and Administration

In 1956 there was a general reorganization of scientific research in Japan, and all national research stations and institutes concerned with agriculture were placed under the authority of the Agriculture, Forestry and Fisheries Research Council. The Council is responsible for personnel and budget, the development of major research programs, cooperative research between the central and provincial stations and universities and for determining the major research programs.

This Council is an advisory group to the Minister of Agriculture, Forestry and Fisheries who appoints the seven members for terms of four years (11). It consists of eminent scientists and officials of the government. Responsibilities of the Council include:

- Formulation of basic plans for research and investigation in agriculture, forestry, animal husbandry, fisheries and the well-being of farmers and fishermen.
- Coordination of business affairs related to national research institutes.
- Monitoring conditions and achievements of research.
- Guidance in management of institutes.

Decisions made by the Council are carried out by a Secretariat which is purely an administrative organization.

Centralization vs. Decentralization

From the beginning of modern scientific research in Japan, there was the recognition of the need for central (national) funding and for coordination of effort. Concurrently, however, it was acknowledged that agriculture is a highly location-specific endeavor and that research must be carried out in a variety of ecological settings. The Assigned Experiment System in which rice varieties were originated at national centers and then adapted in regional stations to suit local conditions was a brilliant combination of approaches and was remarkably successful.

Prefectural research stations have gradually achieved more and more autonomy. The division of labor between national and local stations is now quite broad. There is considerable overlap. In general, the national stations work on projects that will apply to broad areas and prefectural stations concentrate on local considerations. Thus the national centers are most basic in their orientation and the prefectural stations more applied.

National research centers are larger than prefectural stations, reflecting the needs of more basic research. Overall, in 1977 (8) the National Ministry employed 3,400 researchers and 3,000 staff, located in 30 different research and experimental stations. The 47 prefectives employed 7,000 researchers and 11,000 staff in a total of 379 stations.

A trend toward centralization is apparent in the construction of Tsukuba Science City. This research complex is an attempt by the national government to promote science and technology generally and to provide researchers with excellent and unique facilities. Eventually 43 research institutes and a National University will be located in this city. Thirteen of these institutes are affiliated with the Ministry of Agriculture, Forestry and Fisheries. One feature of the city will be a Research Information Center that will collect and centralize research information from Japan and from the world literature.

Funding

Most agricultural research in Japan is financed by the government. This is a direct result of the agricultural situation in that country. Because of the small size of the landholdings, most advances in productivity have come from biological technology rather than from the use of machinery. Because higher-yielding varieties and alternate methods of cultivation are nonexclusive by nature, these advances do not lend themselves to patenting. There has been little incentive, therefore, for private research. An exception to this is a small amount of work carried out to develop small tillers, the appropriate alternative to ride-on tractors.

The marked difference between the involvement of private enterprise in the agricultural and non-agricultural research in Japan is illustrated below.

ALLOCATION OF EXPENDITURES AND STAFF TO AGRICULTURE AND NON-AGRICULTURE IN PUBLIC AND PRIVATE RESEARCH IN JAPAN, 1972

Type of Research Institution	Expenditures		Staff	
	Agriculture	Nonagriculture	Agriculture	Nonagriculture
University	35%	14%	40%	24%
Public				
National government	17	4	17	3
Local government	44	2	40	2
Private	4	80	3	71
Total	100%	100%	100%	100%

Source: Hayami, Y., 1975. A Century of Agricultural Growth in Japan. University of Minnesota Press.

A great deal of fundamental research that has application to agriculture is carried out in universities. The greater part of the funds to support this research comes from grants-in-aid from the Ministry of Education.

Higher Education in Agricultural Research

There is little in the way of direct interaction between universities and government research stations in Japan. Agricultural experimental stations are under the authority of the Minister of Agriculture, Forestry and Fisheries while the faculty of the colleges and universities is directed by the Minister of Education. No formal links between experimental stations and universities have been established.

Universities are regarded primarily as teaching institutions, not research centers. Of course a great deal of basic research that is related to agriculture is carried out during graduate training. Hayami (9) suggests that the separation came about originally because there was pressure for research stations to carry out applied work that had immediate application; this orientation was totally different from the interests of university officials.

Private Industry in Agricultural Research

Ruttan (8) pointed out that there are more than 400 private and semi-private research organizations in Japan that are concerned with agriculture. These organizations encompass not only livestock, pasture, fisheries and food processing, but also economics and politics relating to agriculture. It is important to note in the table above that all of these organizations combined expend only 4% of the money spent on agricultural research in any year. Their impact is, therefore, quite small.

Extension

The linkage between agricultural research and extension has traditionally been strong in Japan. The first real national agricultural system was essentially an extension effort, with experienced farmers sent around the countryside to instruct others. This extension program was later absorbed into the National Experiment Station (1). As prefectural experiment stations became established, extension programs were transferred to them.

Villages formed Agricultural Societies for the exchange of information of this sort. Under the Agricultural Association Law of 1899 these societies began to develop extension programs with government subsidies. Extension workers were trained in agricultural training centers attached to the prefectural experiment stations. The Agricultural Cooperatives Law of 1947 formalized cooperatives into more influential bodies. The input from farmers regarding their needs is thus remarkably strong. Cooperatives in Japan have over five million members and employ about 400,000 people.

Extension services are now organized and carried out by prefectural governments. The extension programs are separate from the experimental stations and from agricultural colleges. Both the experimental stations and the extension services are based in the agricultural segments of the prefectural governments, so there is ample opportunity for close cooperation. In many cases, senior extension specialists are based in experiment stations (4).

Extension services are heavily subsidized by the central government. About 40% of the extension budget is provided from this source (9).

Overall Research Effort

As mentioned earlier in this paper, agricultural research is carried out mostly by the government (59%) and the universities (38%) with private industry involved to only a very small extent. This lack of involvement is attributed to the fact that farms are small in size and therefore innovations like large-scale machinery are not viable products for research.

Research expenditure in higher education is concentrated largely in the national universities and within them in the attached research institutes. The research institute is not an outgrowth of the university, but is annexed to it. While there is overlapping of responsibilities and joint appointments on science faculties and institutes staff, the two are nevertheless organizationally separate and functionally distinct. These research centers are used jointly by researchers from the national, public and private universities.

The national research institutes are attached to a Ministry or Agency and have played a leading role in the promotion of science and technology in the industrial economy. They undertake basic research. The status of researchers in the national research institutes is no different from that of members of university faculties. They bear the same titles, receive remuneration on the same scale, and are organized into research units under the same Chair system as in the university proper. Arrangements can be made to permit university professors to consult openly with private firms. Similarly, classrooms and university laboratories can be opened to industrial research personnel, and industrial laboratories can be viewed as extensions of the university's own teaching facilities at the level of post-graduate research.

When research as a whole is considered, the proportion of government involvement is quite different. In most advanced countries the greatest share of investment in research and development is provided by the government but in Japan the percentage of government research investment is very small when the system is considered as a whole, rather than just that segment that deals with agriculture. For example, Japan's 1977 scientific and technological research investments, comprising governmental, academic and industrial types, totaled 3,320.7 billion. Of the 1977 total, private corporations accounted for 57% or 1,882.2 billion, universities and colleges 28% or 934 billion, and research institutions, including special governmental or semigovernmental types, 15% or 504.4 billion.

The government assists in the development of technology by the private sector in areas other than agriculture. One way in which this is done is to encourage the formation of inter-business cooperation in the formation of research programs. This is the opposite approach from that of the United States government which uses anti-trust laws to prevent cooperation between firms in the same business sector. Within the Japanese research associations the Government provides tax incentives and even direct grants or subsidies. These subsidies may provide for equipment or facilities that are needed for the research or may pay for the development of a new piece of machinery on an experimental basis.

There is also a Research and Development Corporation which takes in hand promising ideas or research results and farms them out for industrial development, bearing the cost until success or failure is apparent. Government banking institutions also provide some low-interest loans to encourage the industrialization of new technology. The Government is endeavoring to create a climate that is most amenable to the creation of new technology in the private sector.

According to Ozawa (11) invariably, the future direction of Japan's research efforts points to more comprehensive and more coordinated approaches, more central planning. What is at stake is no longer so much individual firms' competitiveness as the long-term viability of the entire Japanese economy. Consequently, the direction of research efforts is changing from private to public, from fragmentary to more comprehensive, from simple to more sophisticated, and from uncoordinated to more centrally organized. It is expected that this new trend will expand the government's role in planning, coordinating and financing Research and Development. In fact, such role enlargement is already recognized by government planners.

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FEDERAL REPUBLIC OF GERMANY

Agricultural Situation

In the Federal Republic of Germany about 55% of the country's area is used for agricultural production. The structure of German agriculture is characterized by the following factors: (1)

- The predominance of small owner-operated family farms.
- The major role played by part-time farming.
- A relatively low percentage of rented land.

Currently farmers account for only 6.5% of the German working population. During the period of 1960-72, the agricultural labor force decreased by one-third. In 1972 it represented 7% of the total labor force. Today, more than half of Germany's farmers are part-time farmers, fitting farming into their spare time, but living off their pay from other full-time occupations (4).

Another feature of German agriculture is the increasing area of unused agricultural land. In 1973, unused agricultural land occupied some 272,000 hectares as against 150,000 hectares in 1966. Idle land is estimated to amount to about half a million hectares by 1980 (1). The land is not being idled by any government policy program but is the result of socioeconomic factors (1).

Agriculture's share in the German economy, as in most industrial nations, is relatively low; about 3% of the gross domestic product (1).

Several projections have been made concerning the long-term development of German agriculture. In 1972 the Annual Report on agriculture by the Federal Government stated that the total demand for food could be expected to grow by no more than 1% annually during the 1970s. Consequently, the corresponding value added by agriculture would not be greater than the income expectations of some 1.1 to 1.5 million persons occupied in agriculture by the early 1980s (1).

Farm numbers decreased by somewhat less than one-third over the decade 1946 to 1974. Roughly speaking, farms of less than 20 hectares decreased by one-third in number while the larger ones increased by the same proportion. The overall trend in the number of farms and the size of holdings are outlined in the chart on the following page.

Farm sizes in many cases are inadequate for making the most of modern production techniques. Productivity in agriculture, however, continues to rise steadily, mostly due to the constant outflow of labor. Overall agricultural output increases by around 2% annually (1).

About three-quarters of domestic food and feed demand is covered by home production (61 percent only if production is taken net of imported foodstuffs). Imports of food are important and have been rising constantly. In the past, Germany was the largest importer of agricultural goods within the European Economic Community. German farm exports, however (only about one-fifth of import values) have also risen in the past. Intra-EEC trade is most important for both imports and exports.

Animal production accounted for almost four-fifths of domestic production during the last decade (1).

Agricultural Objectives

The objectives of agricultural policy pursued by the Federal Government are based on the Agricultural Act of September 5, 1955 and the Treaty of Rome. The 1973 report on the state of agriculture (Agrarbericht) summarizes these policy aims under four central headings:

- Improvement of living conditions in rural areas and equal participation in the general economic development and well being.
- Supply of high quality goods at reasonable prices.
- Contribution towards a solution of world food and agricultural problems and improvement of agricultural trade relations.

FULL-TIME AND PART-TIME FARMS IN 1973

('000)

	FARM SIZE IN HECTARES				TOTAL	TOTAL IN 1965
	1-5	5-20	20-50	50 AND OVER		
Total farm number	344	426	174	24	968	1,252
of which:						
Full-time farms	26	218	150	21	415	512
Part-time farms[a]	57	96	17	2	172	323
Spare-time farms[b] ...	261	112	7	1	381	418

a. Farms operated by persons with off-farm jobs but where farming yields the major part of the operator's income (Zuerwerbsbetriebe).

b. Farms operated by persons with off-farm jobs where farming provides a supplementary income only (Nebenerwerbsbetriebe).

SOURCE: Agrarbericht 1974. Table 104.

- Maintaining, reestablishing and developing the overall and general capacities and utilities of nature and landscape.

Agricultural policy is meant to serve in the first instance the people living, working, or seeking recreation in the rural areas. The Federal Government considers agricultural policy not solely as sectoral economic policy with the main task of insuring food supplies. Agricultural policy measures have become an integral part of a policy aiming to solve central problems of society (1).

Under Government policy, the participation of the German people in agriculture, forestry, horticulture and fishing in the general economic development is to be achieved by a variety of coordinated, comprehensive measures, linking activities in the agricultural, economic, regional, social and educational fields and aiming at the overall development of rural regions. This includes creation of off-farm employment in order to facilitate transition from full- to part-time farming or the giving up of farming altogether (1).

This policy takes account of the fact that the number of those obtaining satisfactory incomes from agriculture alone will decrease strongly in the future. This development results from the expected further upward trend of nonagricultural incomes and the relatively slow increase of demand for food products (1).

The resulting consequence of a sufficient outflow of labor into other sectors is largely accepted by the people in agriculture. On the part of the nonagricultural German population the understanding has increased that it is a duty of the State to keep structural changes within socially acceptable limits and to mitigate as much as possible the hardships that may arise (1).

The importance of part-time farming in agricultural policy is undisputed. It is not relegated to a secondary role in relation to full-time farming. The existence of a socioeconomic category of part-time farmers particularly encourages various specific and desirable aspects and qualities in agriculture.

Germany has introduced a variety of acts, schemes and programs to improve the conditions in agriculture. In 1972, a comprehensive development and adjustment plan was launched. Its aim was to create viable farm units, mostly through investment aide, and to help outgoing farmers through financial support and social measures.

Agricultural Research and Policy

The Federal Government considers food policy of equal importance to agricultural policy. This includes all measures aiming to establish a well-functioning food market enabling consumers to obtain high-quality foods at reasonable prices.

The consumer is to be protected against risks to health, fraud and deception. These policies have a clear impact on agricultural research policy (1).

The protection of the environment has become a predominant objective of general policy and research policy, touching directly or indirectly on all important issues of agriculture and food policy. The Federal Government therefore, takes these aspects into consideration within the context of all agricultural policy measures affecting research policy (1).

The Ministry for Food, Agriculture, and Forests is the branch of the executive government which is responsible for agriculture. In spite of its orientation toward farm interests, the Ministry reflects more of a concern in its organization for the consumer.

The ministry is not a "classical" ministry like those of foreign affairs, justice, defense or even agriculture found in many national governments which are oriented very specifically toward defending a certain clientele (2).

It is the stated aim of the research work carried out by the Federal Ministry of Food, Agriculture and Forestry to implement and support food and agricultural policies of the government. This research is primarily conducted in Federal Research Centers. The work of the Federal Research Centers is oriented toward tasks of the Federal Ministry of Food, Agriculture and Forestry but to a certain extent toward those of other ministries. Current priorities are given to the various programs in the following areas; (7)

- Consumers' Policy in the Food Sector

- Quality of Production and Products

- Market and Price Policy
- Development of Rural Areas
- Forestry and Forest Industry
- Fisheries
- Social Policy in Agriculture
- Environment

Currently there are some 1,500 individual research projects being carried out by the Federal Research Center which come under the following four main subject areas: (7)

1. Food Research

The basis for this research carried out by the Centers of the Federal Ministry of Food, Agriculture and Forestry is the agricultural product. The main subjects for research are:

- The improvement of the quality of food in terms of its physiological effect, its taste and its utility value.
- The improvement of the protection of the consumers by reducing the content of unwanted substances.
- The development of new and the improvement of existing technology for food processing.
- The improvement of diets in private and large kitchen units.

It is, above all, the Federal Research Centers for Nutrition, Milk, Meat, Cereal and Potato Processing, Horticultural Plant Breeding, the Federal Biological Centre for Agriculture and Forestry, as well as the Institute for Food Technology and Packaging and the German Research Center for Food Chemistry that work in this field.

2. Production-oriented Research

It promotes technological progress in agriculture and forestry, its main objectives being:

- Improvement of quality and reduction of costs in animal and plant production by means of breeding and technological progress.
- Development and extension of production techniques calculated to reduce any risk of pollution taking into account possibilities to increase productivity.
- Protection of animal health as well as diagnosis and control of animal diseases.
- Animal welfare.

It is, above all, the Federal Research Centers for Agriculture, the Federal Biological Center for Agriculture and Forestry and Federal Research Centers for Vine Breeding, Animal Virus Diseases, Horicultural Plant Breeding and for Forestry and Forest Products that are concerned with these topics.

3. Environmental Research

Numerous research projects carried out in the field of food and production show the impact of such activities on the environment and thus the close link between research on environmental problems in the agricultural field and other fields of research. The objectives of the research projects are:

- To reduce the negative effects on the environment caused by agriculture and the impact of environmental pollution on agriculture.
- To promote the favorable contribution of agriculture to the improvement of the environment.

- To protect, manage and develop nature and landscapes especially with regard to the steadily increasing need for food.

All Federal Research Centers conduct work on the first two subjects. In the field of "Nature and Landscape" it is mainly the Federal Research Center for Nature Conservation and Landscape Ecology that is dealing with these problems.

4. Research on Economics and Social Aspects

The scope and importance of this field has been increasing considerably in recent times. The Federal Ministry of Food, Agriculture and Forestry therefore approved a new program to increase research in this field. The main subjects are:

- Management in the production and processing sector.

- Agricultural structures and social policy--social economy in rural areas.

- Market analyses and market policy.

- International agricultural and trade policies.

- Consumers' policy in the food sector.

The specialized institutes of the Federal Research Centers for Milk (also for meat, cereals, potatoes, fruit and vegetables) of the Federal Research Center for Forestry and Forest Products and of the Federal Research Center for Nutrition are working on the various scientific projects.

It is the aim of the research work carried out by the Federal Ministry of Food, Agriculture and Forestry, to implement food and agricultural policies to support the administration.

The Federal Research Centers have the task to work out the scientific bases for the decisions to be taken by the Federal Government on food, agriculture and forestry policy matters as well as consumers' policy and to improve, at the same time, scientific knowledge in this field in the interest of the general public.

In order to increase the efficiency of the 13 Federal Research Centers and to safeguard, at the same time, the economical and effective use of funds as part of the reorganization of research in the Ministry, cooperation among the Federal Research Centers was intensified in 1969 (7).

A Senate of Federal Research Centers was established consisting of the Heads of the Centers as well as seven other scientists who are elected for two years. The main task of this Senate is the coordination of the scientific work conducted by all Federal Research Centers, participation in the elaboration of the Research Plan of the Federal Ministry of Food, Agriculture and Forestry and the elaboration of a Joint Research Program on the basis of the program of each center.

The German Government considers long-term research planning a necessity. In 1975, the Federal Government decided that all ministries which spend more than 10 million DM on research and development must work out from 1976 onward so-called research program plans.

The ministries concerned then elaborated common principles for such a plan. According to these common principles the Federal Ministry of Food, Agriculture and Forestry together with its Research Centers worked out its own General Research Plan for 1976-79 (7).

This General Research Plan identified, on the basis of the policies pursued by the Ministry, concrete research needs which were brought into close relation with the research work conducted by the Federal Research Centers. In addition, this general plan is supplemented by a project plan which is revised annually, consisting of the present research projects of the Federal Research Centers.

The information on the projects is intensified by annual reports on the research work already completed. Both informations and the political planning of the Ministry are the basis for the further development of research planning.

In addition to the General Research Plan including all Research Centers, each Center works out its own plan called "Programe budget." These are to list and explain the medium- and long-term programs for the development of the activities of each Center taking to consideration the specific tasks assigned to the Center, its structure and the objectives and programs of the Ministry.

The Ministry annually publishes an anthology of all scientific findings of the Centers called "Annual Report on Research Work in the Federal Ministry of Food, Agriculture and Forestry." Each Center publishes its own annual report separately (7).

Relations with Higher Education and Extension Services

Germany is a country with a long tradition of government concern for science exercised over long periods in its history not by one national administration but by a number of regional state governments. This has resulted in a multi-centered science establishment and strong regional differences in development.

The Universities in Germany involved with science are some of the oldest in the world and were originally very closely related to the state government. With the development of science in the 19th century the universities expanded into new fields and, side by side with teaching, research became increasingly important. Technological training and research, however, developed in institutions outside the University. Some of these achieved in the course of time the status of Technische Hochschulen recognized as equal to that of the traditional universities (8).

At the same time, public administration became increasingly involved with the problems and techniques of science, and various regional institutes for all types of research, control and testing were founded.

At the beginning of the 19th century, Britain was regarded by those interested in agricultural improvement as the "school for agriculture." By the end of the century, leadership in the application of science to agriculture belonged to Germany (9).

German experience in the organization of agricultural research and education provided the models for institution-building in other countries. The rapid development of agricultural science in Germany during the latter part of the 19th century was part of a more comprehensive effort by Germany to take advantage of advances in science, technology and education to overcome the gap in resource endowments, industrial and agricultural technology and in economic and political power between Germany and Great Britain (9).

Public support for education and research as an instrument of economic progress represented a major institutional innovation in the 19th century. The German states generously financed a whole gamut of institutions, erecting buildings, installing laboratories and above all maintaining competent and, at the highest level, distinguished faculties (9).

A key factor, in the German approach to the development and application of science and technology in the field of agriculture was the establishment of publicly supported agricultural experiment stations. The first publicly supported agricultural experiment station was organized at Mockern, Saxony in 1852. During the next 25 years, 74 publicly supported agricultural experiment stations were established in Germany. The German style of agricultural experiment station has been adapted in the United States, Japan and other countries (9).

The present structure of agricultural research in Germany is a product of the forceful personalities of scientific leadership in the 19th century and of the political forces which shaped the development of the German nation (9).

The modern research university was a German invention. Unlike other science in the early 19th century, the agricultural sciences were not institutionalised in the new research university system. For a time they developed as separate agricultural academies. These academies, which were primarily teaching institutions, were established in all of the German states during the first half of the 19th century. During the second half of the 19th century the agricultural academies lost their preeminence in the German agricultural education system as the agricultural sciences were brought within the framework of the new university system. Agricultural faculties were established in the universities at Halle (1863), Leipzig (1869), Munich (1874), Konisgberg (1876), Breslau (1880), Berlin (1880) and later at Heidelberg, Giessen and Kiel (9).

These new agricultural facilities did not fill the need for research directly focused on the problems of agricultural production. The solution to this problem by most German states was the establishment of agricultural experiment stations. These experiment stations were established outside of the university system and did not have teaching obligations. They were strongly supported by local farmers' organizations and chambers of agriculture.

The decentralized agricultural research system that evolved in Germany was a direct consequence of the federal structure of the German political system. There was no central ministry of agriculture during the period of the German Empire. The first Ministry of Agriculture, Food and Forestry was established under the Weimar Republic in 1919. A move toward centralization of research began in the early 1900s. In 1905 the Biologische Anstalt fur Land-und Forstwirtschaft for plant protection was founded. It developed a network of stations throughout the whole of Germany.

The establishment of the Kaiser Wilhelm-Gesellschaft (now the Max Plank-Gesellschaft) in 1910 also contributed to the more central direction of agricultural research. Although it was initially founded to support research in the basic sciences, it soon incorporated fields such as genetics, plant breeding, agricultural engineering and others. At present the Max Plank-Gesellschaft zur Forderung der Wissenschaften has 48 institutes of which the large majority are for the natural sciences. The Society has greatly contributed to the development of science and influenced the universities (9).

Apart from these large groups of establishments and organizations for scientific research and development, there exist a great number of public and private institutes for agricultural research, many of which depend on financial support from the state. For example, the Deutsche Forschungsgemeinschaft (German Research Association) dates back to an organization founded in 1920, when scientific life threatened to stagnate after the war. It does not conduct research of its own, but promotes research at universities, in public institutes and through the support of private individuals.

Funding

Under the German constitution, the individual states (Lander) are responsible for education at all levels, including the universities. Consequently, there are 11 State Ministries of Education but no Federal (Bunn) Ministry. For example, the Federal Government has "competitive legislative competence" if a certain problem cannot be effectively solved by State (Land) legislation, if land legislation might be contrary to the interests of other Lander or if Federal legislation is required to secure uniformity.

Education and science are constituent elements of the national structure and unity, and should be viewed on the national scale. Much of the organizational and financial task is too complex and too great to be solved by the states alone. The Lander have, therefore, established the Permanent Conference of Education Ministers as an instrument of policy coordination particularly in the field of educational policy.

The States have agreed on the common financing of such national science organizations as the Max Planck Society for the Promotion of Science and German Research Associations and have established a common fund for the financing of new universities.

On the basis of administrative agreements the Federal Government cooperates with the 11 states in the financing of the national scientific organization just mentioned, the expansion of existing universities, and student stipends.

Relations with Industry

Industrial research is mainly a matter for industry itself to organize and finance, though cooperative research in industry began in the 19th century, regular state support was developed only after the last war.

The main common principle is that, in a liberal economy such as the German, industry is basically responsible for its own research but that government will assist industry, where necessary in the interest of the national economy. Government aid may be either direct (i.e., aid from public funds, research) or indirect (i.e., manpower training facilities, information services, etc.). Scientific research of interest to industry is conducted in government research establishments in special state-supported research institutes, in the Universities, and in private industry. Of these, the first and the last have a greater share of applied research and development, while fundamental research predominates in the other two. None of these four groups can be looked at in isolation, since there is a close-knit network of organizational, personal and financial links between all of them.

University System

Under the constitution, the individual Landers are responsible for education at all levels, including the universities. Consequently, there are 11 Ministries of Education, but no Federal Ministry.

The universities carry the main responsibility for the pursuit of fundamental research and the training of scientists. Lack of pertinent statistics hinder making a quantitative analysis of university research. On the whole, emphasis on research seems particularly strong in Germany. The traditional description of the essential tasks of the university is Forschung und Lehre, "research and teaching," in that order.

Education and science are recognized as constituent elements of the national structure and unity. Also there is agreement that the organizational and financial task is too complex and too great to be solved by the Lander alone.

The Lander have, therefore, established the Permanent Conference of Education Ministers as an instrument of policy coordination, particularly in the field of education policy. This group has agreed on the common financing of such national science organizations as the DFG and MPG and has established a common fund for the financing of new universities.

On the basis of administrative agreements, the Federal Government cooperates with the Lander in the financing of the national scientific organizations just mentioned, the expansion of existing universities, and student stipends. The major part of university financing for other items is borne by the Lander, though Federal support is increasing.

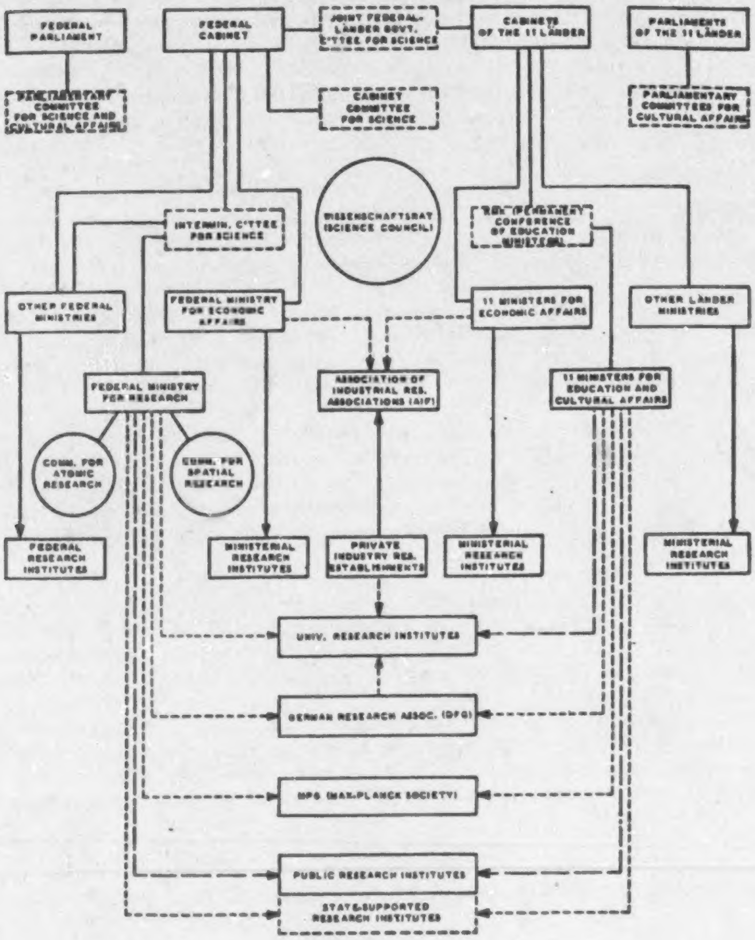
A key element in support of university research in general is the Deutsche Forschungsgemeinschaft (German Research Association, DFG), and the Max Planck Society for the promotion of Science (MPG). At the beginning of this century it became apparent that new fields of scientific research were opening up for which the existing universities were not sufficiently equipped to cover. These societies have greatly contributed to the development of science and influenced the universities.

The universities are themselves mainly responsible for the structure and content of education and research in their institutions. The universities are represented nationally in the Westdeutsche Rektorenkonferenz (West German University Rectors' Conference) which has set up special committees on international problems of higher education.

The conference frequently acts in an advisory capacity to the governments and, since it represents the knowledge, influence and prestige of the academic world in general, its word carries weight in science policy discussions. It also has close institutional and personal links with the administrative and advisory bodies of DFG and MPG, so that these organizations often act in concert on policy matters.

The relationships which the universities have with the overall organization of science and technology can be seen in the diagram on the following page.

GERMANY. — THE ORGANISATION OF SCIENCE AND TECHNOLOGY


FEDERAL PARLIAMENT
FEDERAL CABINET
JOINT FEDERAL-LÄNDER GOVT. C'TTEE FOR SCIENCE
CABINETS OF THE 11 LÄNDER
PARLIAMENTS OF THE 11 LÄNDER
PARLIAMENTARY COMMITTEE FOR SCIENCE AND CULTURAL AFFAIRS
CABINET COMMITTEE FOR SCIENCE
PARLIAMENTARY COMMITTEES FOR CULTURAL AFFAIRS
INTERMIN. C'TTEE FOR SCIENCE
WISSENSCHAFTSRAT (SCIENCE COUNCIL)
KMK (PERMANENT CONFERENCE OF EDUCATION MINISTERS)
OTHER FEDERAL MINISTRIES
FEDERAL MINISTRY FOR ECONOMIC AFFAIRS
11 MINISTERS FOR ECONOMIC AFFAIRS
OTHER LÄNDER MINISTRIES
FEDERAL MINISTRY FOR RESEARCH
ASSOCIATION OF INDUSTRIAL RES. ASSOCIATIONS (AIF)
11 MINISTERS FOR EDUCATION AND CULTURAL AFFAIRS
COMM. FOR ATOMIC RESEARCH
COMM. FOR SPATIAL RESEARCH
FEDERAL RESEARCH INSTITUTES
MINISTERIAL RESEARCH INSTITUTES
PRIVATE INDUSTRY RES. ESTABLISHMENTS
MINISTERIAL RESEARCH INSTITUTES
MINISTERIAL RESEARCH INSTITUTES
UNIV. RESEARCH INSTITUTES
GERMAN RESEARCH ASSOC. (DFG)
MPG (MAX-PLANCK SOCIETY)
PUBLIC RESEARCH INSTITUTES
STATE-SUPPORTED RESEARCH INSTITUTES

SOURCE: Organisation For Economic Cooperation and Development (8)

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UNITED KINGDOM

Agricultural Situation

Although Britain is a densely populated, industrialized country relying on imports for nearly half of its food, agriculture continues to be important to the national economy. With a total annual output worth 5,308 million pounds in 1975, agriculture employs 662,000 people or 2.7% of the total employment and generates approximately 2.7% of the gross domestic product (1).

Agriculture utilizes 19 million of the 24 million hectares of land (47 million of the 60 million acres). There are about 272,000 statistically significant farming units in Britain. Some 42% are very small units, mostly farmed part-time accounting for less than a tenth of the industry's total output. Of the 170,000 full-time farm businesses some 39,000 are classified as larger farm businesses (capable of employing four or more men full-time); these account for some 14.5% of all farms producing more than half the total agricultural output in 1975. There are about 53,000 medium-sized (two to three men) and 64,500 small farm businesses (1). Amalgamation of small farms into larger, more viable units has been encouraged by successive governments.

The average size of full-time holdings in Britain is 105 hectares (259 acres) based on total area which includes crop, grazing and woodland (2).

The increasing use of intensive production methods both in crops and in animal husbandry has led to increasing specialization. Three-fifths of the full-time farms in Britain are devoted mainly to dairying, cattle or sheep; one in six is a crop farm and the rest specialize in pigs, poultry, horticulture or mixed farms. The British climate is well suited to grassland farming. The latter are important parts of the economy of most farms (1).

Between the two world wars British agriculture suffered a long depression which reached its lowest point about 1930. In the late 1920s and early 1930s the need for some form of State assistance to agriculture became pressing as a consequence of the depression in agricultural prices which was part of a general fall in commodity prices (1).

From this period onward, the main object of the government's agricultural policy was to find methods of supporting domestic agriculture without prejudice to Britain's position as a world trading nation (2).

The role of the government in relation to agriculture is mainly as a provider of financial support and a provider of technical and advisory services. The success of the government role from the period of about 1930 where overall production reached its lowest point is seen in the steady expansion in production and in yield per acre of arable land which has taken place since 1936 (2).

There has been an almost continuous growth in output from British agriculture since the Second World War, with the total volume of output increasing by over 40% during the past 20 years. This growth has not been steady throughout the period, but has tended to go in waves (2).

Britain now produces over half of its total food requirements or 65% of products that can be produced in its temperate climate. Over the period 1964-65 to 1974-75 the degree of self-sufficiency for all food requirements rose from 51 to 53% and for indigenous-type food from 64 to 65% (2).

These increases in production have been achieved with a decreasing use of manpower and land. Over the same period there has been a considerable increase in capital investment as well as the development of intensive methods of livestock and crop production and continued application of scientific technology. It has been estimated that this has resulted in an average annual rate of increase in labor productivity of approximately 4.5% over the period of 1964-65 to 1975-76 (1).

Agricultural Objectives

Government policy today is founded on the Agriculture Acts of 1947 and 1957, the Agriculture and Horticulture Act of 1964, the Agriculture Act of 1967 and, increasingly since 1973, on the provisions of the common agricultural policy of the European Community. (Britain began to take part in the European Community system of agricultural support under the common agricultural policy in 1973) (1)(2).

The main objective of government agricultural policy as set out in the 1947 Act continues to be:

> "A stable and efficient agricultural industry capable of producing such part of the nation's food and other agricultural produce as in the national interest it is desirable to produce in the United Kingdom, and of producing it at minimum prices consistent with proper renumeration and living conditions for farmers and workers in agriculture and an adequate return on capital invested in the industry."

The functions of government in relation to agriculture in general are mostly exercised by the agricultural ministers: for England and Wales the Minister of Agriculture, Fisheries and Food; the Secretary of State for Wales; for Scotland the Secretary of State Scotland; and for Northern Ireland the Secretary of State for Northern Ireland.

The Advisory Council for Agriculture and Horticulture provides the Minister and his department with independent advice on any agricultural or horticultural subjects pertaining to England or Wales. In Scotland, the Scottish Agricultural Advisory Council advises the Department of Agriculture and Fisheries on matters of policy and administration referred to it (1).

In 1966 an Economic Development Committee for agriculture was established, comprising representatives of farmers, workers and landowners, as well as official and independent members.

Britain joined the European Economic Community (EEC) in 1973 as a result of adopting the Common Agricultural Policy. The United Kingdom has free trade within the EEC in agricultural products. With entry in EEC, the government saw the need for expansion in agricultural production further reinforced. The government's position with regard to the needs for agriculture in EEC was stated in a position paper in 1972 as follows: (2)

> "It is in the national interest that United Kingdom agriculture should be in a position to take advantage of the opportunities of entry into EEC. The essential thing is to ensure that expansion of production takes place early, and not merely after the potential advantages under the EEC system have begun to make themselves felt. Our share of the enlarged EEC market--including our own home market--will depend on the competitiveness of our farmers. This means that we should aim to improve the already good record of productivity gain in our agricultural industry from the start of the transition by stimulating the investment which is needed for expansion and by securing the advantages of increased scale. The Government's aim is to encourage producers to start taking decisions for further expansion now."

A White Paper on future agricultural policy in Britain, Food from Our Own Resources, was published on April 17, 1975. It examined the prospects and policies for food production from 'our own resources' of land and labor over the 'next five to ten years.' The White Paper was published following discussions on the long-term prospects for British agriculture held between the Government and representatives of farmers, workers, landowners, the food and drink industries and consumers.

Taking account of likely future levels of world and European Community food prices in sterling terms, and of the competing claims on national resources, the Government concluded that:

a) The likely levels of world and community prices for major foodstuffs between 1975 and the early 1980s, and the risks of possible shortage and sharp food price fluctuation justified a policy of expansion of food production in Britain.

b) The net product of the agricultural industry should be capable of a continuing expansion of about 2-5% a year on average, and that this was the objective at which the Government and the industry should aim.

c) Within the overall objective most benefit was likely to come from higher output of milk (with its concomitant the beef from the dairy herd) and sugar beet. Cereals and sheepmeat should also make a significant contribution.

The Government said in the White Paper that it would frame agricultural policies in the light of these conclusions and that the objective of Government policy would be 'to provide farmers with a prospect of stability in their returns at levels encouraging the greater home production which would give the country an insurance against periods of shortage and higher prices.'

The Government has consistently made clear that, in its view, the policy of expansion and the priorities set out in the White Paper remain valid and should continue to guide decisions on agricultural policy (1).

Agricultural Research Policy

Government resources for the support of agricultural research in the United Kingdom first became available through the Development and Road Improvement Act of 1901. In the 19th century agriculture research was initiated by private individuals, usually innovative estate owners or farmers (8).

In 1911, a Development Commission was established to coordinate the use of funds available under the Act through the Agriculture Departments of England and Scotland. Grants were made to various institutes and university departments (8).

In 1931, an Agricultural Research Council was established to serve as scientific advisors to the Development Commission and the Agricultural Departments. In 1954, concern for agricultural research was removed from the Development Commission and the two Agricultural Departments assumed responsibility for administering and support of the state-aided institutes on the advice of the Agricultural Research Council (8).

The Council expanded its role in 1956 when responsibility for all state-aided institutes in England and Wales were transferred to it. In 1959, responsibility for food research plus several agriculturally related institutes previously administered by the Department of Science and Industrial Research were all transferred to the Council. In 1959, responsibility for the Council's budget was transferred to the Department of Education and Science.

By the early 1960s, the Agricultural Research Councils mandate was to review and facilitate research progress, promote new research where necessary and ensure as far as possible that manpower and resources were used to the best advantage (8).

The Council at that time supervised the state-aided research institutes, administered its own institute and units, supported fundamental and applied research in universities, and trained recruits into the agricultural service.

During this period the Council's style was low-key and diffuse. According to a Council Document, "No central direction of research is attempted because the Council believes that able research workers must be allowed freedom to develop their individual interests within the general requirements of the service." Attempts were made to assure a balance between individual freedom in research and relevance of research effort for agricultural improvement. The mechanisms used for this purpose included the meetings and seminars held by the standing and technical committees of the Council. It was not felt necessary for all research planning and results to receive formal review. Formal project instruments were not employed on a systemwide basis (8).

By the late 1960s, there was increasing concern in the United Kingdom that the administration of research, including agricultural research, had not kept pace with the growth of personnel and resources. At that time a distinct division of research responsibilities had emerged. Much of the research supported by the Agricultural Research Council was removed from immediate problems of agricultural production. The more short-term or adaptive research was conducted by the Ministry of Agriculture, Fisheries and Food's Agricultural Development and Advisory Service.

In 1971 a personal report by Lord Rothschild, head of the Central Policy Review Staff in the Cabinet Office, recommended a drastic restructuring of the research carried on by several research councils in the United Kingdom including ARC. The Central Policy Review Staff advises the Cabinet on long-term policy matters and this staff is popularly known as the "think-tank."

At the time of the Rothschild report, the Agricultural Research Council was financed by the Department of Education and Science. The latter was advised on its budget by a Council for Scientific Policy, a general scientific policy group which in dealing with the various research councils (i.e., ARC) was mainly concerned with strategic and fundamental research.

The basic reform recommended in the Rothschild report and later accepted by the government was the establishment of a customer-contractor principle in the funding of some of the research carried out by ARC and other research councils in the United Kingdom. Key issues raised by the Rothschild report in subsequent debate and in a government White Paper prepared by the parliamentary Select Committee on Science and Technology were the following:

1) The principle that scientists financed by the government should be accountable for what they do and have a responsibility to meet the needs of their country.

2) The application of the customer-contractor principle as a particular means of achieving that accountability.

3) The wider issue of science policy; how can scientists through their research help to meet their country's needs when the government has no clearly defined long-term policies.

The effect of acceptance of the proposals was that the Agricultural Research Council would receive over half of its funds in the form of contracts (customer-contractor principle) for specific applied research from the Ministry of Agriculture, Fisheries and Food (MAFF).

Agricultural Research

The greater part of agricultural and food research and development is carried out in the 30 research institutes and the ten units which comprise what is known as the Agricultural Research Service of the United Kingdom. The Agricultural Research Service is an informal title. It refers to those institutes and units over which the Agricultural Research Council has financial control.

All ten units and eight of the institutes are under the direct control of the ARC, and it is responsible for the administration of government grants to 14 independent institutes in England and Wales. The units, which are attached to universities, have been established by the ARC under distinguished scientists. In Scotland, eight independent research organizations receive grants through the Department of Agriculture and Fisheries for Scotland and guidance in research matters from the ARC. Development and experimental work is also carried out in Scotland by the three agricultural colleges (1).

Agricultural Research Council

Under its original charter, granted in 1931, the ARC was responsible to the Committee of the Privy Council for Agricultural Research. The Science and Technology Act of 1965 transferred responsibility for all the government research councils to the Secretary of State for Education and Science, and a new charter with appropriate amendments to include responsibility for food research was given Royal Approval in 1967. Amendments to this charter, made primarily to give effect to the new relationship with the agricultural departments (customer-contractor principle), were approved in 1973.

The Council consits of a chairman and not less than 18 nor more than 21 members. The Chairman and between 12 and 15 members are appointed by the Secretary of State Education and Science, not more than four by the Minister of Agriculture, Fisheries and Food and not more than two by the Secretary of State for Scotland. Of those appointed by the Secretary of State for Education and Science, six may be persons appointed on account of their general experience or interest in agriculture or the food industry and the remainder, after consultation with the President of the Royal Society, on account of their qualifications in one of the sciences relating to agriculture or food (1).

Definition and Review of Programs

Advice on priorities for all State-aided R&D in agriculture and food in England, Wales and Scotland is provided by the Joint Consultative Organization (JCO) and is presented to the three funding bodies which are its sponsors--Agricultural Research Council (ARC), the Ministry of Agriculture, Fisheries and Food (MAFF), the Department of Agriculture and Fisheries for Scotland (DAFS). The JCO comprises members of the farming and food industries, scientists, economists and members of the departments' professional, technical and administrative services. The organization consists of five Advisory Boards concerned with Animals, Arable Crops and Forage, Horticulture, Food Science and Technology, and Engineering and Buildings (1).

Each board has 20 or more members, including scientists, members of the industry, officials (MAFF and DAFS) and an economist. These boards examine current research in relation to what research is required and the need of various interested parties and make recommendations regarding priorities. They taken into account not only the research conducted by the ARC but also the research and development conducted by MAFF and DAFS at their own institutes, experimental farms, etc. (9).

One of the functions of the Joint Consultative Organization is to give advice on which MAFF can base its commissions to the ARC. The Chief Scientist for MAFF is responsible for framing the Ministry's R&D program, for commissioning the work and allocating funds to it and for keeping it under review. He is also responsible for providing general scientific advice to the Minister over a broad range of Ministry policy. The Chief Scientist and his staff maintain contact with those concerned with R&D in other Government departments, in the Research Councils, in industry and in the universities (1).

Funding

The total governmental funds devoted to agricultural research in the financial year 1978-79 was 59.3 million pounds. This corresponds to just under 1% of the gross output of the agricultural industry. Ten years ago government agricultural research spending was approximately 2% (6). In the fiscal year 1976-77, total government expenditure on agricultural research plus food research was estimated at about 65 million pounds. This agricultural and food research was carried out pricnipally by the Agricultural Research Council, the Government agricultural departments and the food research associations. Some research is also conducted by the National Environment Research Council, universities and other agencies.

As a result of the customer-contractor principle a substantial proportion of the research and development work undertaken by the ARC is now commissioned and paid for by the MAFF. The remainder of its funds come chiefly from a parliamentary grant-in-aid through the Department of Education and Science. In 1975-76 the council's total budget amounted to 36 million pounds (1).

Recent history in the United Kingdom has seen an end to the rapid increase in funds devoted to research as in most developed countries of the world (9). The Government has had increasing doubts about the benefits that their country was deriving for all research. Factors contributing to the end of the period of rapid budget expansion for agriculture have been the change in the public attitude toward science and technology and the realization that within the United Kingdom the organizational system for dealing with agricultural research had not kept pace with the increase in personnel and resources during the recent growth phase (9).

The three major sources of funds for agricultural research are the Ministry of Agriculture, Fisheries and Food, Agricultural Research Council from the science budget of the Department of Education and Science and the Department of Agriculture and Fisheries for Scotland (DAFS). For example, in Fiscal 1978-79 the total budget (59.93 million pounds) from these three sources was made up by 25.42 million from the Ministry of Agriculture, Fisheries and Food, 23.75 million from ARC and 10.76 million from DAFS. Under the new organization for research since 1971 with the application of the customer-contractor principle, approximately 55% of ARC's budget is in the form of contracts for applied work and 45% of the budget comes from the Department of Education and Science for long-term startegic and fundamental research (9).

Relations with Industry

Industrial concerns manufacturing weedkillers, insecticides, fertilizers, animal feeds, agricultural tractors and implements undertake research on a considerable scale and in many cases maintain experimental farms and estates (1).

Britain has one of the highest tractor densities in the world, with 542,000 tractors in 1975 or one to every 13 hectares (32 acres) of arable land. Britain is the third largest producer of tractors in the world. Research, development and testing of farm machinery are carried out by the National Institute of Agricultural Engineering at Silsoe in Bedfordshire, and the Scottish Institute of Agricultural Engineering at Penicnik in Lothian, both the responsibility of the British Society for Research in Agricultural Engineering (1).

The Agricultural Research Council's Food Research Institute and Meat Research Institute were set up following the ARC's assumption of responsibility for food research in 1959 (8).

Representatives of the farming and food industries are members of Joint Consultative Organization (JCO) which guides ARC, MAFF and DAFS on matters of priorities for all State-aid R&D in agriculture and food. Also members of industry are members of each of five boards, Animals, Arable Crops and Forage, Horticulture, Engineering, foods which are the working groups of JCO (9).

Relations with Higher Education and Personnel Training

The Agricultural Research Council makes grants to universities for special investigations. The Agricultural Research Council's Research Units are attached to universities. They are as follows: (1)

- Unit of Animal Genetics, Institute of Animal Genetics, West Mains Road, Edinburgh EH9 3JN

- Unit of Developmental Botany, 181A Huntingdon Road, Cambridge CB3ODY

- Unit of Invertebrate Chemistry and Physiology, University of Sussex, Falmer, Brighton, Sussex BN1 9QJ

- Unit of Invertebrate Chemistry and Physiology, University of Cambridge, Department of Zoology, Downing Street, Cambridge CB2 3EJ

- Unit of Muscle Mechanisms and Insert Physiology, Department of Zoology, University of Oxford, South Parks Road, Oxford OX1 3PS

- Unit of Nitrogen Fixation, University of Sussex, Falmer, Brighton, Sussex BN1 9QJ

- Unit of Reproductive Physiology and Biochemistry, Animal Research Station, 307 Huntingdon Road, Cambridge CB3 0JQ

- Unit of Soil Physics, 219c Huntingdon Road, Cambridge CB3 0DL

- Unit of Statistics, University of Edinburgh, 21 Buccleuch Place, Edinburgh EH8 9LN

- Statistics Group, University of Cambridge, Department of Applied Biology, Pembroke Street, Cambridge CB2 3DX

- Systemic Fungicides Unit, Wye College, Ashford, Kent TN25 5AH

In addition, the ARC is closely connected with the highly developed agricultural educational system of the United Kingdom.

Ten universities in England (Bath, Cambridge, Exeter, Leeds, London, Manchester, Newcastle upon Tyne, Nottingham, Oxford, Reading), two of the constituent colleges of the University of Wales (Aberystwyth and Bangor), three universities in Scotland (Aberdeen, Edinburgh and Glasgow) and one in Northern Ireland (Queen's University, Belfast) provide degree and post-graduate courses in agriculture, agricultural sciences or agricultural economics. The National College of Agricultural Engineering at Silsoe, Bedfordshire, offers degree and post-graduate courses in agricultural engineering. Three-year sandwich courses leading to a Higher National Diploma are available at eight agricultural colleges in England and Wales and there are nearly 50 local authority and other agricultural colleges providing full-time courses on different aspects of agriculture, horticulture, forestry and farm management. A center for European agricultural studies is based at London University's Wye College at Ashford. A Centre for Agricultural Strategy was set up at the University of Reading in 1975 to provide an independent and objective assessment of British agriculture with a view to developing long-term strategies.

In Scotland the three agricultural colleges which provide the advisory services and undertake development work are also teaching establishments, associated with the agricultural departments of the neighboring universities. They mainly provide sandwich courses leading to Higher and Ordinary National Diplomas, post-diploma courses and certain short courses. In Northern Ireland degree courses in agriculture and food science are provided at Queen's University, Belfast. Courses below this level are provided at three residential colleges run by the Department of Agriculture (1).

Extension Services

The Agricultural Development and Advisory Service of the Ministry of Agriculture, Fisheries and Food has the prime function of an advisory and development service to the agricultural industry (5).

In England and Wales scientific, technological and management advice and services are available through the Agricultural Development and Advisory Service (ADAS) which operates mainly from the Ministry's regional and divisional offices. The service also helps to identify problems requiring investigation and research, to suggest priorities for such work and, where appropriate, to contribute to possible solutions. ADAS provides free and impartial advice to landowners, farmers and growers but charges are made for certain laboratory services.

ADAS was formed in 1971. Its main aims are threefold: to help the agricultural and horticultural industries to improve their productivity further; to provide technical advice in forming and implementing Government policy; and to help in achieving maximum benefit from public investment in research and grant-aided schemes. Among the many services included in ADAS are the Agricultural Service which provides advice to farmers and is responsible for ADAS experimental husbandry farms and horticulture stations; the Agricultural Science Service, which is the specialist scientific service of ADAS, with laboratories at each Regional Center providing a full range of scientific and analytical services and undertaking research, and which includes the Plant Pathology Laboratory which is responsible for the Plant Health and Seeds Inspectorate, and the Pest Infestation Control Laboratory which is responsible for the Regional Pests Organization; the Land Service, which advises on all estate management matters including farm building and land use and which is responsible for the professional aspects of the farm capital grant scheme; the Land Drainage Service; and the Veterinary Service including the Central Veterinary Laboratory and Veterinary Investigation Centers.

In Scotland the agricultural advisory service is provided by the three regional independent colleges which are financed almost entirely by public funds. The nature of service is similar to that provided by the ADAS and covers all branches of advice.

Advisory work in Northern Ireland is under the direction of the Chief Inspector of the Department of Agriculture, and Advisory Centers are located in the main provincial towns. The resources of the agricultural colleges, the research centers and the specialist divisions of the department are available to the advisory service (1).

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RELEVANCE TO UNITED STATES AGRICULTURAL RESEARCH

This paper was not in any way designed to critique the system of agricultural research in the United States. However, one aim was to suggest ways in which aspects of national systems that have proven successful in some other country might find application in the United States. It should be understood that these suggestions are based on an incomplete knowledge of the structure and operation of the United States system. Members of the Advisory Board may have knowledge that will show these suggestions to be redundant; they are offered here only as a stimulus to further discussion for the improvement of the United States system.

Although this review of the national agricultural research systems in six foreign countries is admittedly superficial, there are several features which appear in some or all of these systems that do not seem dominant in the structure of the United States model. A detailed discussion of these facets is beyond the scope of this paper, but brief comments are offered here.

National Policy

Most of the countries examined have developed an overall policy for allocating scientific resources and within that some sort of national council for agricultural research. The council is usually advised by a standing committee comprised of eminent scientists, government officials and representatives of primary producers. The function of this committee is:

- To set and review priorities;
- To ensure maximum coordination of agricultural research;
- To initiate research in new fields as needed; and
- To oversee the implementation of policy with regard to research.

Aaron has pointed out that the main argument for vesting all responsibility for research with such a council or committee holds that a ministry of agriculture cannot provide a desirable research climate, does not have the necessary understanding of the problems of research, is not prepared to invest in speculative research, and is affected by political considerations and influenced by the immediate needs of farmers. There is a danger of a committee of this sort becoming too academic, however, and not being responsive to the needs of the producers. One way to avoid this complication would seem to be to have adequate representation on the committee.

There is no indication that the United States has established a strong policy direction in agricultural research. United States food policy in recent years appears to have been shaped by circumstances rather than by legislation or by the direction of a national committee. Lack of a decisive policy can leave the agricultural sector in a constant state of flux so that long-term planning becomes impossible. A national agricultural policy is regarded as of overwhelming importance in some foreign countries. (Brazil has blamed its lack of progress in the past on the absence of a defined policy.)

The lack of policy has clearly been felt by many scientists in the United States, including the directors of federal research laboratories. A recent GAO survey (1) of 192 directors of federal research laboratories from eight agencies regarding perspectives on the management of their laboratories revealed that a majority of the respondents characterized their working environment as suffering from insufficient policy framework and direction. Further, they suggested that a national policy that had longer range planning commitments would allow for multi-year funding which would improve management operations.

There has been agitation for a clearer United States agricultural policy for some time. Twenty years ago the deans of the land-grant colleges suggested a "National Academy of Agriculture" that would be similar in structure to the National Institute of Medicine that now exists. That this concept is still under active consideration is evidenced by the editorial in Food Technology, November 1980, that discussed this suggestion as a way to meet the need for greater coordination of research effort.

Outside Reviews

In the course of researching this paper it was interesting to discover that many of the national agricultural research systems have been extensively revised in the past several years, such that data on organization and management that is more than a few years old is no longer applicable. These changes in structure resulted in every case from an examination of the system by an independent commission that had no particular political or organizational affiliation and was sometimes international in composition. The criticisms and suggestions of these examiners are taken very seriously and changes are often put into effect very rapidly. India is constantly reassessing the organization of its research effort. Brazil held an investigation in 1972 and by April of 1973 had a completely new structure in place. Many countries covered in this review have a continuing evaluation of the research system by an independent body.

Scientists as Managers

The UNESCO study of the effectiveness of research organizations showed that an extremely important aspect of scientist effectiveness is the feeling of prestige and involvement that the scientist has with a research unit. The single most important aspect of a research unit, as far as the scientist is concerned, is the personality and management ability of the unit director. This fact suggests that management and planning are extremely important skills for supervisory personnel, but these attributes seem to have been little valued in the past. Of the countries examined, Australia has most clearly made an effort to train researchers as managers and supervisors. All supervisory personnel receive in-house training in CSIRO, the research organization of Australia and this is the only staff development undertaken by that organization.

An aspect of managerial responsibility that is of major concern is the amount of control a unit director has over personnel. The GAO survey of federal research laboratories showed that 44% of the respondents felt that there would be "considerable improvement" in the efficiency of operations with a change in the authority to hire and fire.

Other countries have considered this issue also. In the opinion of some United States experts, the restructuring of the Brazilian agricultural system was carried out primarily to free the system from the strictures of the civil service with an overwhelming bureaucracy of inadequate personnel. Australia has a research system that involves no tenure, and in which all promotion is based solely on merit which is determined by peer evaluation.

Rural Society

Many of the countries examined in this report have made a commitment to accommodate progress in agriculture to the preservation of the structure of rural society. India and Japan have focused research on small farm units and on maintaining the integrity of the family-owned farm unit. In many countries (notably Germany and Japan) part-time farmers are the rule rather than the exception, and policies are designed to incorporate this into the national agricultural system. Technology has been adopted to the farm size in these countries rather than the reverse which appears to have taken place in the United States.

Within the United States, there has been a steady decline in small farms. In the United States, farms are classified by size according to income of sales per farm. The table on the following page illustrates the decrease in the number of small units.

Interaction with Private Industry

In many of the countries examined the small size of the farms and the poverty of the farmers has meant that private industry has not been applied to agriculture because the profit motive was not available.

One way in which government and industry was seen to interact, however, was in commodity-oriented research that is jointly funded. In Australia and in Brazil a levy on the sale of a particular commodity provides funds for research on that commodity that will benefit the industry as a whole. Government matches the funds in Australia, so that the amounts involved are quite substantial.

This type of financing of research provides an alternative to that controlled and funded entirely by the government. In a time of restraint on federal spending in the United States this alternative might merit examination. A potential problem with an arrangement of this sort is the representation by scientifically naive producers on the committees that determine directions for research effort.

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-Number of farms by value of sales classes. 1960-79

Year	Farms with sales of--									
	$200,000 and over	$100,000 to $199,999	$100,000 and over 1/	$40,000 to $99,999	$20,000 to $39,999	$10,000 to $19,999	$5,000 to $9,999	$2,500 to $4,999	Less than $2,500	All farms
					Thousands					
1960	NA	NA	23	90	227	497	660	617	1,849	3,963
1961	NA	NA	26	97	239	493	625	576	1,769	3,825
1962	NA	NA	29	106	254	493	589	533	1,688	3,692
1963	NA	NA	31	113	267	491	557	495	1,618	3,572
1964	NA	NA	32	114	268	482	534	469	1,558	3,457
1965	NA	NA	36	125	280	464	508	461	1,482	3,356
1966	NA	NA	43	143	304	445	476	457	1,389	3,257
1967	NA	NA	43	142	299	431	460	445	1,342	3,162
1968	NA	NA	45	149	306	415	439	437	1,280	3,071
1969	16	35	(51)	170	330	400	413	436	1,200	3,000
1970	18	39	(57)	178	326	390	402	423	1,173	2,949
1971	20	43	(63)	187	322	381	391	412	1,146	2,902
1972	27	55	(82)	217	321	367	374	390	1,109	2,860
1973	46	91	(137)	311	329	338	334	341	1,033	2,823
1974	50	100	(150)	331	328	329	322	327	1,008	2,795
1975	48	94	(142)	316	324	328	323	329	1,005	2,767
1976	52	103	(155)	338	323	319	313	314	978	2,738
1977 2/	53	104	(157)	341	320	313	305	307	666	2,409
1978	64	126	(190)	398	323	296	281	275	609	2,370
1979	76	150	(226)	459	327	274	250	242	555	2,333

NA = Not available. See estimation note following table 101. 1/ The numbers in ( ) represent the subtotals of the first two columns. 2/ Based on the 1974 Census of Agriculture definition of a farm.

This table has not taken account of inflation and the consequent movement of farm units into higher income categories. However, the decrease in small sized farms and in total number of farms shows that the decline in smaller farms has continued.

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SOURCE: USDA. Economics and Statistics Service Statistical Bulletin #650. 1979.